DAR/ MARSHALL

Phase III Study of Selected Tether Applications In Space

Contract: NAS8 – 36617

DPD 665 DR – 3

✓ Mid – Term Reveiw

July 10, 1986

Prepared for:

George C. Marshall Space FLight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

(NASA-CR-178900) PHASE 3 STUDY OF SELECTED TETHER APPLICATIONS IN SPACE, MID-TERM REVIEW (Ball Aerospace Systems Div., Boulder) 67 p CSCL 22B

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Introduction

- Guidelines For STS Payload Deployer Design (Dan McMann)
  + Mini – OMV (MOMV)
  + Shuttle Tether Deployer System (STEDS)
- MOMV Design (Dan McMann)
- STEDS Design (Dan McMann)
  + STEDS Control Simulation (John Glaese)
- Cost Modeling (Tim Patton)
- Tethered Platform Analysis (Cal Rybak)
  + Fuel Savings Analysis
- Tasks For Remainder of Program (Dan McMann)

Guidelines for Shuttle Deployer Design

- STS Launch
  + Minimize Weight/Length
  + Meet All STS Safety Requirements
- Deployment/Retrieval In Less than 24 hrs Cumulative of Crew/STS Time
- Payload Weight Range 1,000 to 10,000 kg
- Transfer From 300 km STS Orbit to Maximum 600 km Dropoff
- Minimize Impact on Payload Design/Operation
- No Payload Retrieval Required
- MOMV/STEDS Returned By STS Between Missions

DRM midtrm1

Rationale For MOMV vs OMV Trade

- Operational Cost Data Not Available For OMV
- MOMV Has Lower Launch Cost – lighter weight
- MOMV Takes Less Bay Space – actual launch cost driver
- MOMV Mechanisms Already Developed
- Our Mission Does Not Require Payload Retrieve Capability (No T.V. cameras or supporting software, equip., personell)
- Our Mission Does Not Require On – orbit Refueling Capability
- Want To Compare Systems With Approximately Equal Capabilities

MIDTRM27

MOMV Design

MIDTRM25

MOMV Derived Design Requirements

- Attachment to Payload Accomplished On – orbit
- Self – contained Subsystems
  + Power
  + Thermal
  + Attitude Control
  + Communications & Data Handling
  + Propulsion
- Mission Duration of 48 hours Minimum
- No Subsystem Redundancy
- Recovery by STS After Mission Completion
- Only Mechanical Interface to Payload

MOMV Design Summary

- Structure of Honeycomb and Truss Members
  + Weight: Empty 1400 kg Hyd. 1112 kg = 2511 kg Total
- Hydrazine Propellant System
  + 3 TRDSS Tanks
  + 5 lbf Thrusters
  + Blowdown System
- Attitude Control System Similar to ERBS
  + Always in ERBS Orbit Transfer Orientation
  + Nadir Oriented/ 3 – axis Stabilized
- Communications & Data Handling Through TDRSS
  + Low Data Rate
  + Intermittent Operation Times
- Power System Uses Solar Arrays and Batteries
- Thermal Control Using MLI and Heaters
- Uses 3 MMS/FSS Berthing Latches for Payload Attachment

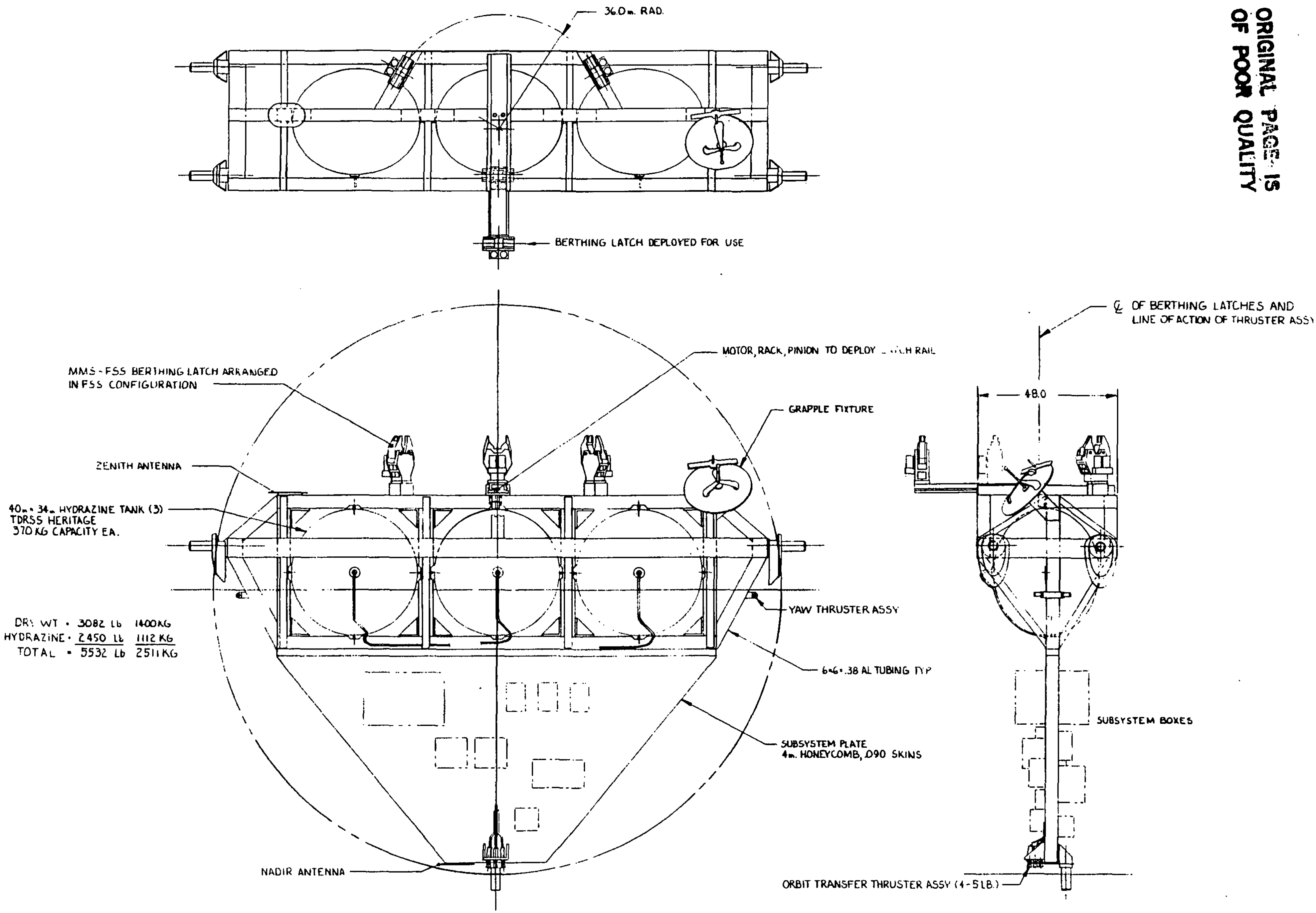
MIDTRM3

MOMV Features

- Optimized to Minimize STS Bay Length
- Uses Flight Proven Hardware & Mechanisms
  - + Hydrazine Tanks – TDRSS Heritage
  - + Berthing Latches – MMS/FSS Heritage
  - + Subsystem Boxes – ERBS Heritage
  - + Propulsion System – ERBS Heritage
- Structure is Fabricated from 6061 – T6 Aluminum & HC Panel
- Designed for 25 STS Launches Including Fracture Considerations (Tanks and Trunions Replaced Once over 25 Missions for Fracture)
- Uses ERBS Proven Low – Thrust Concept for Orbit Raising
- Can Place Payloads Into Circular or Elliptical Orbits

MIDTRM14

MINI - OMV



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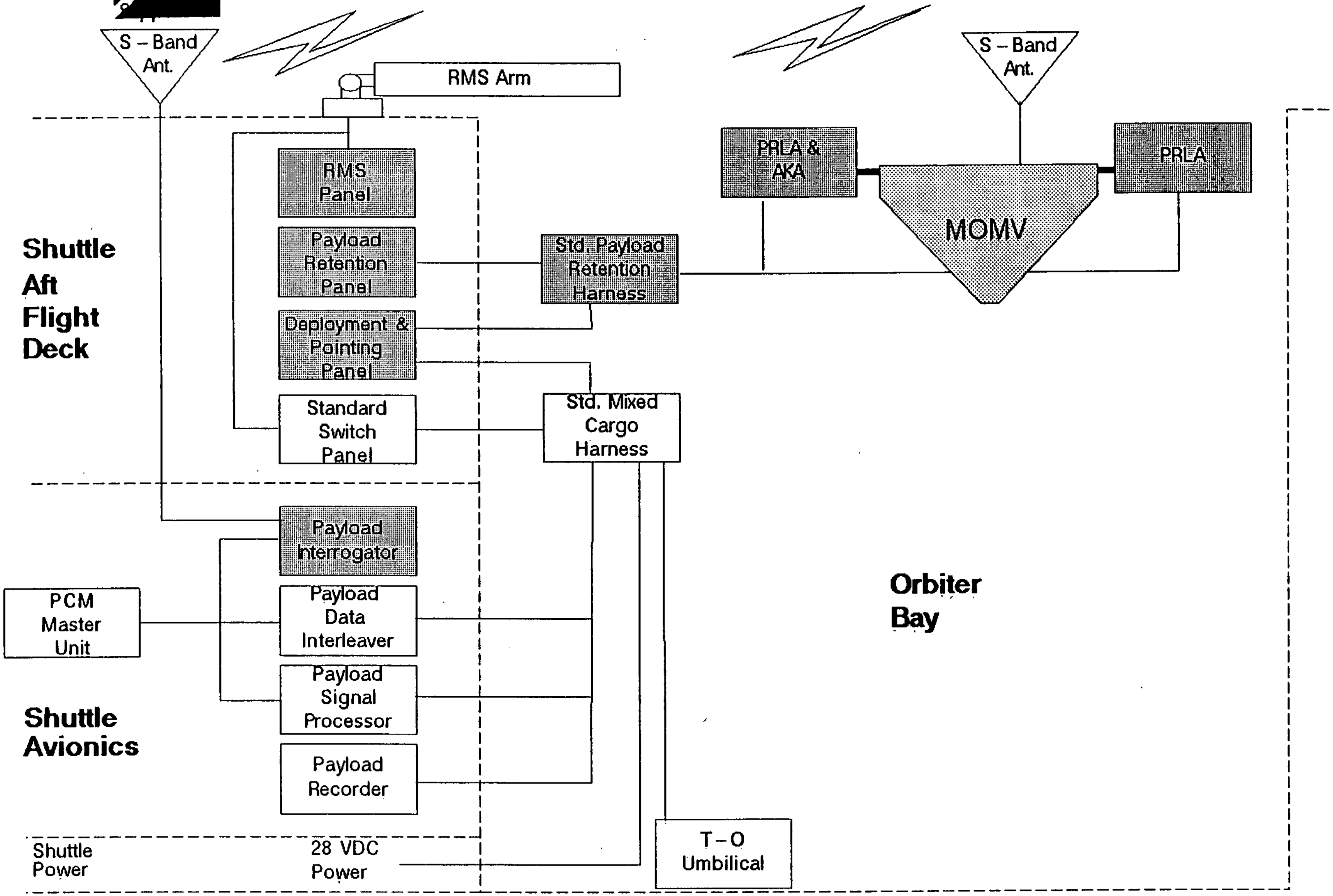
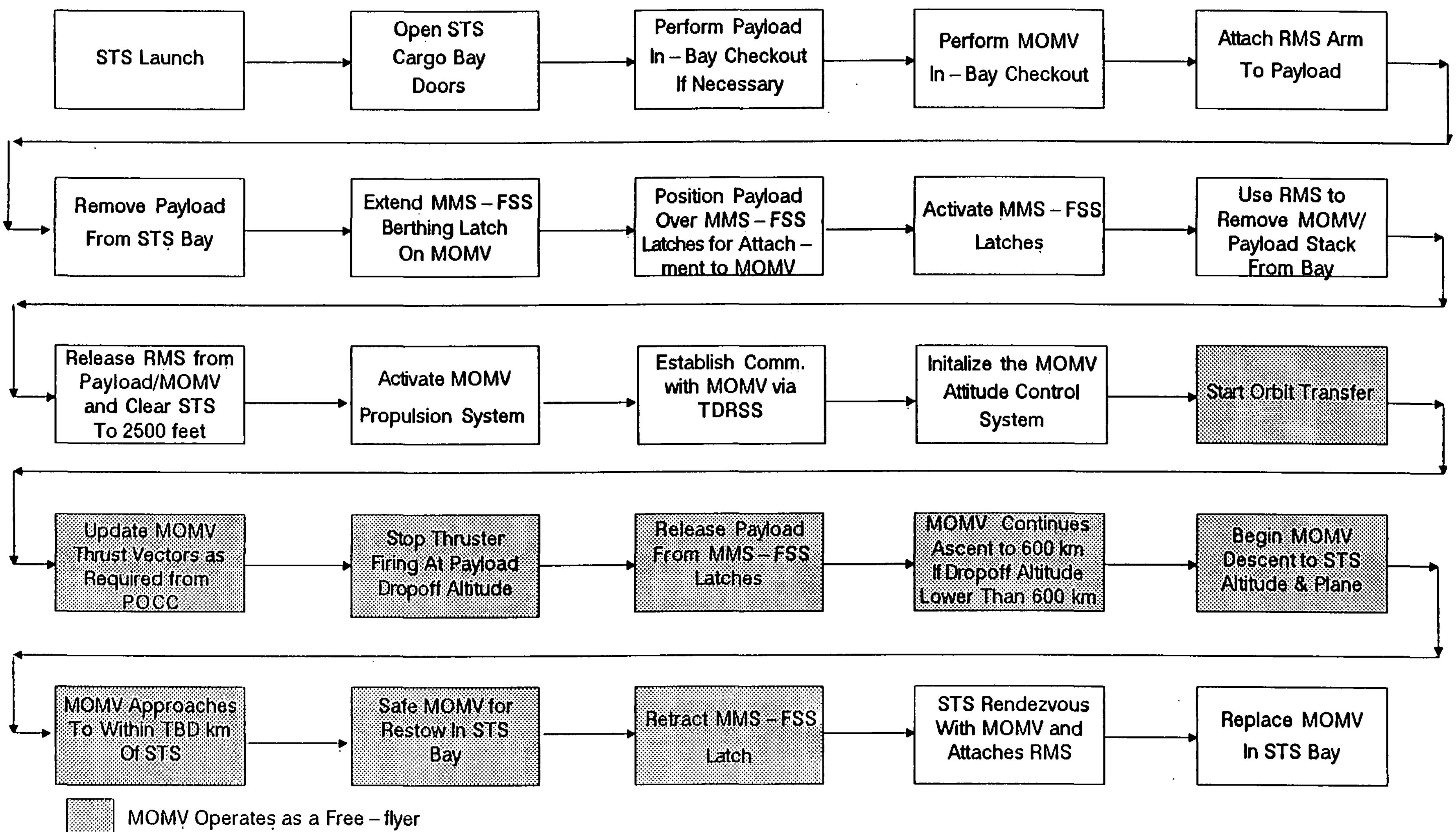
MOMV/STS Electrical Interface



MIDTRM24

MOMV Operational Sequence



DRM MIDTRM4

MOMV Attitude Control System

- Sensors
  - + Horizon Scanner
  - + Triaxial Rate Gyro Package
- Actuation System
  - + Hydrazine Reaction Jets
- Attitude Control Electronics
  - + Process Horizon Scanner Data
  - + Gyrocompass Implementation
  - + Reaction Jet Control Logic

CR MIDTRM12

MOMV Thermal Requirements

- All Sun Angle Vehicle ($-90° < \beta < 90°$)
- 300 to 600 km Orbit
- Operate With/Without Payload Attached
- Maintain Hydrazine to +5/+55°C
- Maintain Electronics to −10/+55°C
- Maintain Batteries to −5/+25°C
- Survive All STS Operational Attitudes

DRM MIDTRM5

MOMV Thermal Design

- MOMV Completely Covered With MLI Blankets
  - + 5 mil Silvered Teflon and .5 mil Aluminized Kapton Covers
  - + 10 Layers .25 mil Aluminized Mylar and Dacron Netting Interior
- Solar Arrays Isolated From Structure
- 30 W Survival Heaters Provided for Each Hydrazine Tank

DRM MIDTRM6

MOMV Thermal Analysis Results

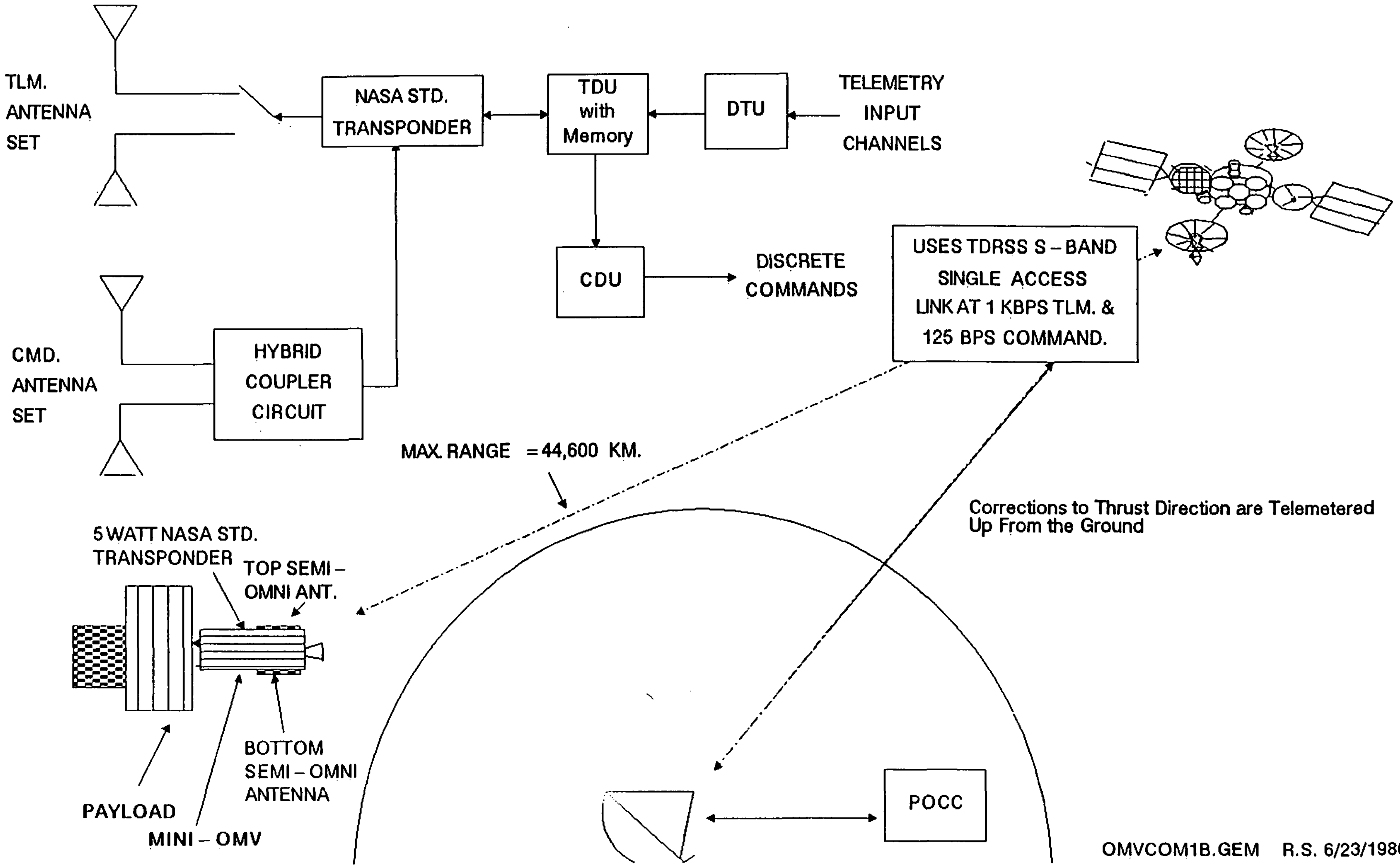
	W/O Payload		With Payload		STS Bay to Earth	
	Cold	Hot	Cold	Hot		
	$\beta = 0^\circ$	$\beta = 90^\circ$	$\beta = 0^\circ$	$\beta = 90^\circ$	$\beta = 0^\circ$	$\beta = 90^\circ$
Elec. Mounting Panel	34.6	52.4	34.0	53.0	−1.0	−13.7
Hydrazine Tank Frame	6.9	19.9	6.9	21.0	4.6	3.8
Hydrazine	5.0 #	17.7	5.0 *	18.0	5.0**	5.0***
Battery	6.9	20.0	6.9	20.9	8.6	26.0

All Temperatures – deg C

7.2 W htr. power
* 13.0 W htr. power
** 8.4 W htr. power
*** 26W htr. power

DRM MIDTRM7

COMMUNICATIONS CONCEPT FOR MOMV



OMVCOM1B.GEM R.S. 6/23/1986

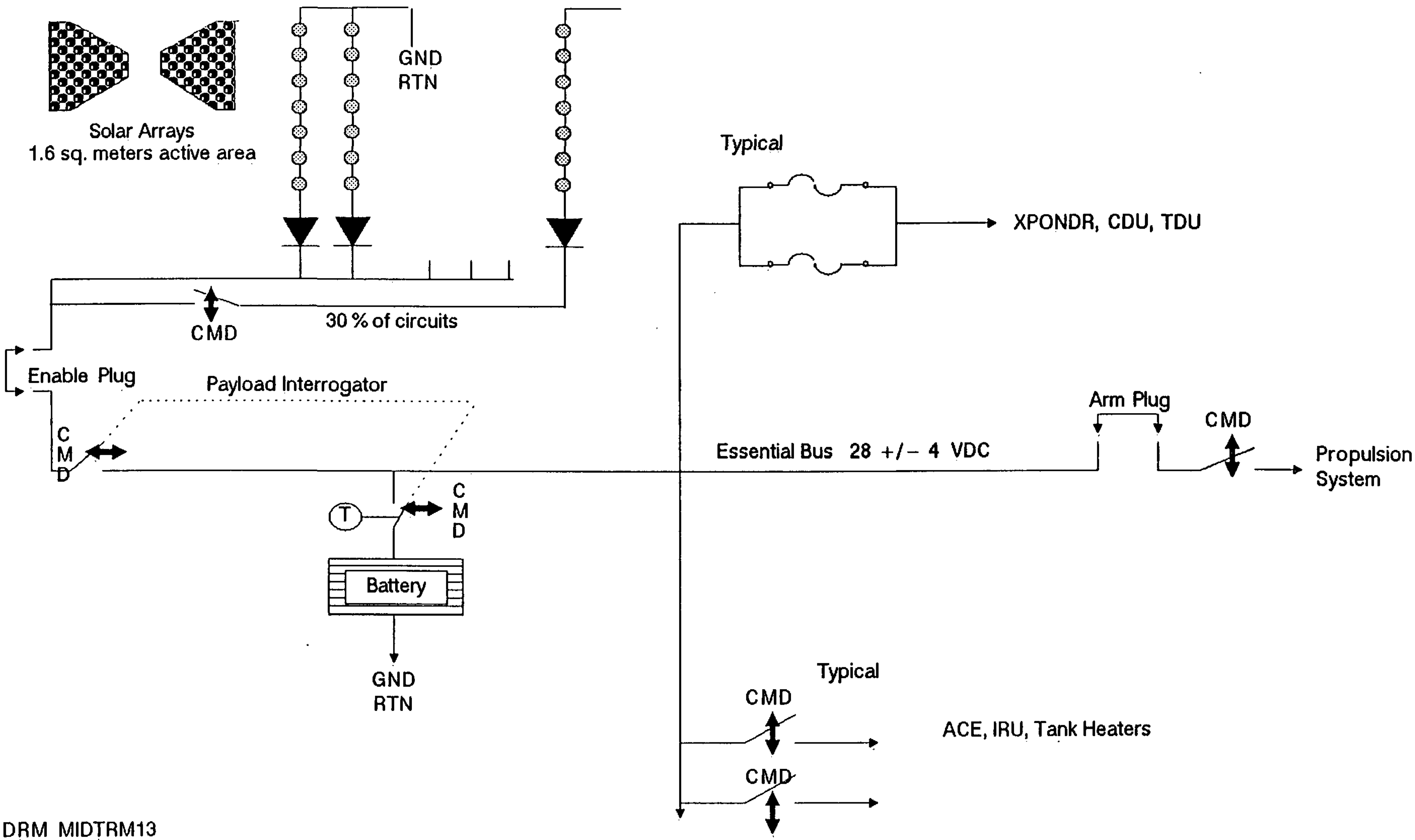
Mini-OMV C&DH Component List

#	COMPONENT NAME	Wt. (KG)	L (CM)	W (CM)	H (CM)	PWR (W)		% ON	AVERAGE POWER (WATTS)
1	TRANSPONDER	6.5	33.1	14.1	14.0	17.5	RCV ONLY	99.0	17.3
						45.5	XMT.& RCV	1.0	0.5
2	TLM.DIST.UNIT	7.1	22.9	20.3	15.4	5.0		100.0	5.0
3	DIGITAL TLM. UNIT	4.5	20.6	12.7	8.9	13.0		100.0	13.0
4	CMD. DECODER UNIT	4.5	16.5	12.7	8.9	5.0	OPERATE	1.0	0.1
						1.5	STANDBY	99.0	1.5
5	TOPSIDE CMD/TLM ANTENNA	1.0	34.3	25.4	1.9	0.0		0.0	0.0
6	LOWSIDE CMD/TLM ANTENNA	1.0	34.3	25.4	1.9	0.0		0	0.0
7	MISC. SW'S,CABLE,ETC.	4.0	SMALL STUFF FITS IN EASY			0.0		0.0	0.0
						TOTAL AVERAGE POWER			37.3

NOTE:

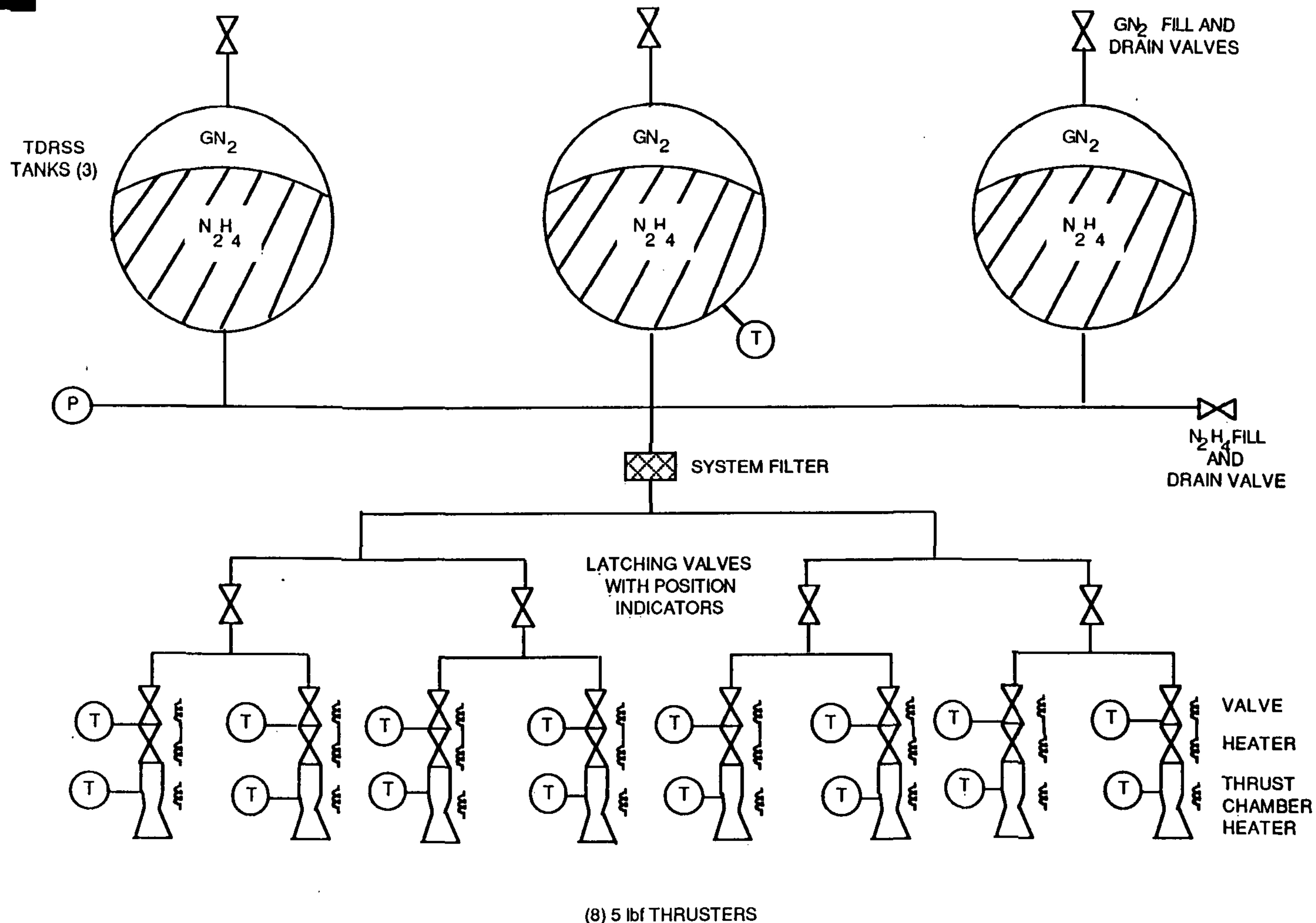
THIS COMPONENT LIST IS BASED ON A SYSTEM SIMILAR TO THAT USED ON ERBS AND CRRES WITH A LOT OF HERITAGE. WAYS TO CUT POWER WOULD BE TO USE A DIFFERENT COMMAND AND TELEMETRY SYSTEM DESIGNED WITH POWER CONSERVATION IN MIND. ALSO, ONE COULD CONSIDER PUTTING COMMAND RECEIVERS ON A STORED PROGRAM COMMAND TO COME ON AT SET INTERVALS. IT WOULD BE ADVISIBLE ,IN THIS CASE, TO HAVE A SEPERATE HI-REL SIMPLE RESET TIMER DESIGNED TO TURN THE RECEIVERS ON IF A RESET HAS NOT BEEN RECEIVED IN A FIXED INTERVAL (LIKE 24 HOURS).

MOMV Electrical Power System Concept



DRM MIDTRM13

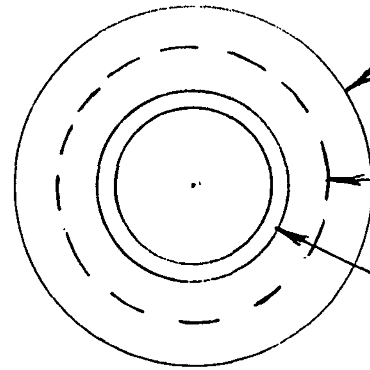
MOMV PROPULSION SUBSYSTEM



(P) PRESSURE TRANSDUCER

(T) TEMPERATURE SENSOR/THERMISOR

MOMV MISSION TIME FOR 300 KM ROUNDTRIP IS TWO DAYS



SYNODIC PERIOD FOR MINIMUM TRANSFER TIME (TIME UNTIL MOMV AND ORBITER CELESTIAL LONGITUDES ARE AGAIN EQUAL)

$$P_s \approx \frac{P_{450}\,P_{300}}{P_{450} - P_{300}} = 46.2 \text{ HOURS}$$

ASSUMES UNIFORM ASCENT, DESCENT AND VERY SMALL PAYLOAD DROP – OFF TIME

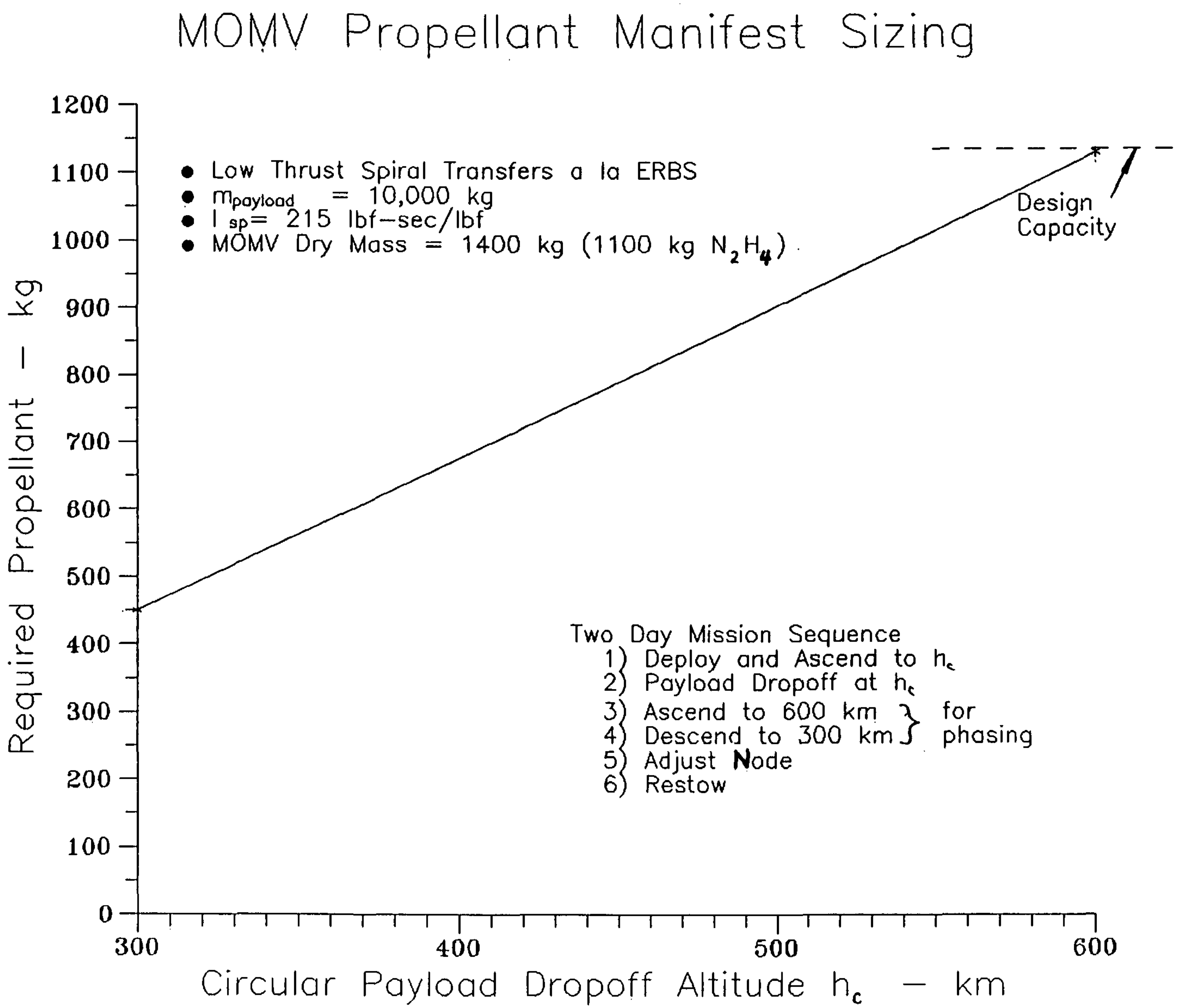
IF DROP – OFF ALTITUDE IS LESS THAN 600 KM THEN MISSION TIME WILL BE LONGER UNLESS MOMV COMPLETES ROUNDTRIP CIRCUIT TO 600 KM

PART OF FUEL ALLOCATION IS USED FOR MOMV NODAL READJUSTMENT DUE TO ALTITUDE DIFFERENCE

ΔV PARALLEL TO ORBIT NORMAL IS REQUIRED AT MAXIMUM DECLINATION, WHICH ROTATES PLANE AND CHANGES Ω, BUT NOT i

MAXIMUM PLANE CHANGE IMPULSE IS REQUIRED WHEN i = 45°

FOR 300 KM TRANSFER TO 600 KM CIRCULAR AND BACK OVER TWO DAYS WITH i = 45°, THE DIFFERENTIAL NODAL REGRESSION IS 0.86° WHICH REQUIRES A PLANE CHANGE OF 0.61 DEGS AND A ΔV OF 82 METERS PER SECOND


MOMV Propellant Manifest Sizing
• Low Thrust Spiral Transfers a la ERBS
• $m_{payload}$ = 10,000 kg
• I_{sp} = 215 lbf-sec/lbf
• MOMV Dry Mass = 1400 kg (1100 kg N_2H_4)
Design Capacity
Two Day Mission Sequence
1) Deploy and Ascend to h_c
2) Payload Dropoff at h_c
3) Ascend to 600 km
4) Descend to 300 km
for phasing
5) Adjust Node
6) Restow
Required Propellant – kg
Circular Payload Dropoff Altitude h_c – km
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
300
400
500
600

STEDS Design

MIDTRM26

STEDS Derived Design Requirements

- Attachment To Payload Accomplished On – Orbit
- Disposable Tether
- Use a Non – Swinging Release
- Self – Contained Payload Tether Release Mechanism
- Deployment Times Up To 24 Hours Acceptable
- Tether Line Must Clear STS Structure By TBD Meters
- Must Manage Energy of Deployment

MIDTRM17

STEDS Design Summary

- Lightweight Truss Structure (Total Wt. = 1290 kg inc. tether)
- Energy Dissipation Using Light Weight High Temperature Quartz Lamps
- Remote Mate/De – mate of Tether With Payload
- Active Cooling for Generator, Brake and Electronics Using STS Fluid Loop
- Design Minimizes STS Bay Length
  + Deployable Boom
  + Non – Standard Tether Canister Shape

STEDS Features

- Optimized to Minimize Weight & Bay Length
- Structure is Fabricated From 6061 – T6 Aluminum Stock
- Designed for 25 STS Launches Including Fracture Considerations
- Incorporates Boom to Allow Bay Positioning Flexibility
    + Deployed Using Torsion Springs in Boom Hinges
    + Located and Stowed with Small Motor, Cable
- Designed for One Time Use of Tether
    + No Reel, Level Wind or Motor Required
    + Tether is Cut at the STEDS as Deployment is Completed
- Tether End Effector (P/L Interface) is Remotely Mateable
    + Uses RMS
    + Autonomous from Payload
    + Independently Powered and 'Smart'

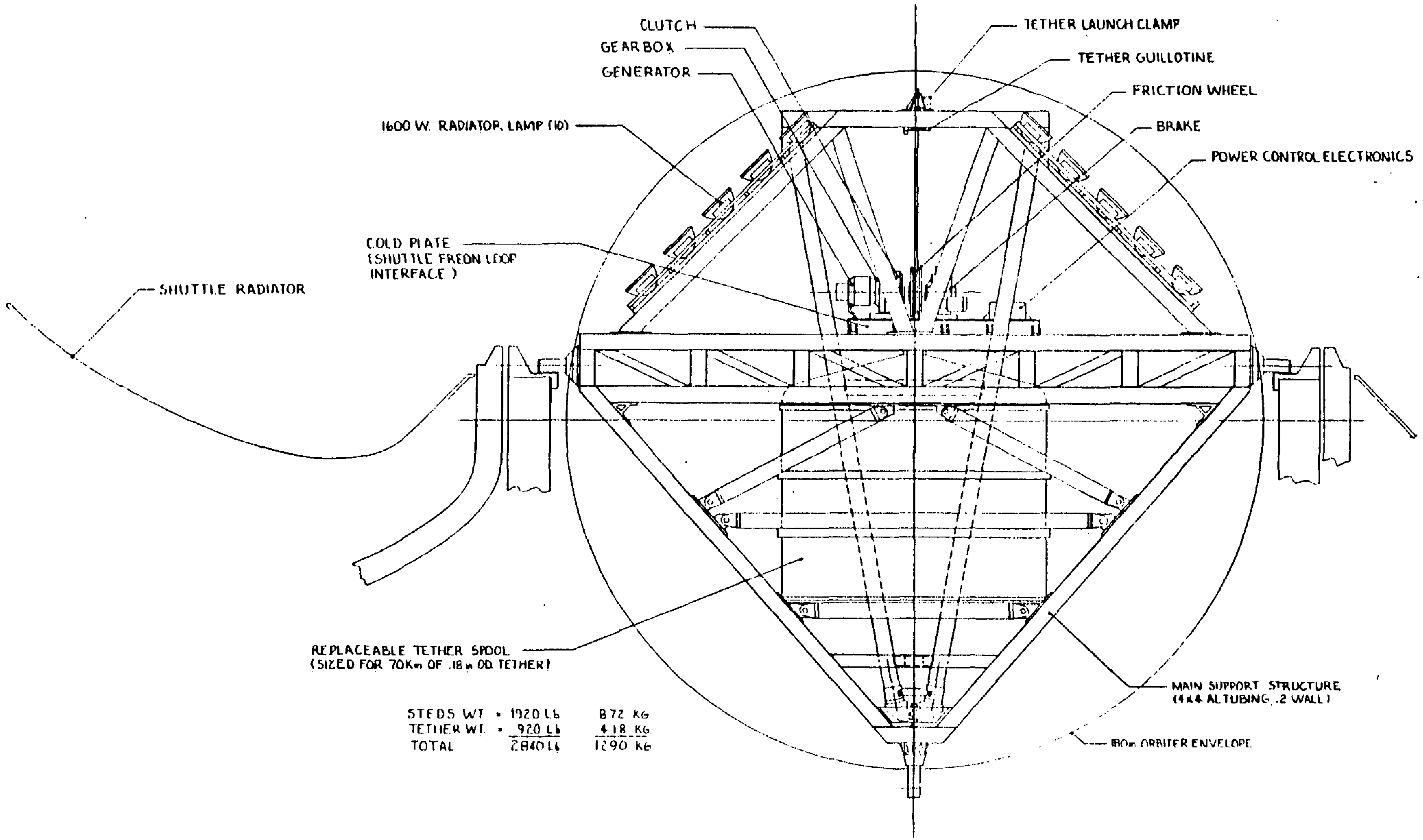
MIDTRM15

STEDS Features (Continued)

- Tether Tension Control System
  + Generator – Aircraft Heritage, Electrodynamic Braking To Provide Tension
  + Gearbox – To Increase Generator Speed and Improve Performance
  + Clutch – Disengages Gearbox From Generator
    * Accommodate Low Tension Initial Deployment
  + Friction Wheels – Provides Friction Needed to Control Tether Tension
    * Designed to Handle Tensions Caused by 10,000 kg @ 70 km
  + Brake – Used at End of Deployment to Arrest Final Motion
  + Radiator Lamps – to Dissipate Generated Energy

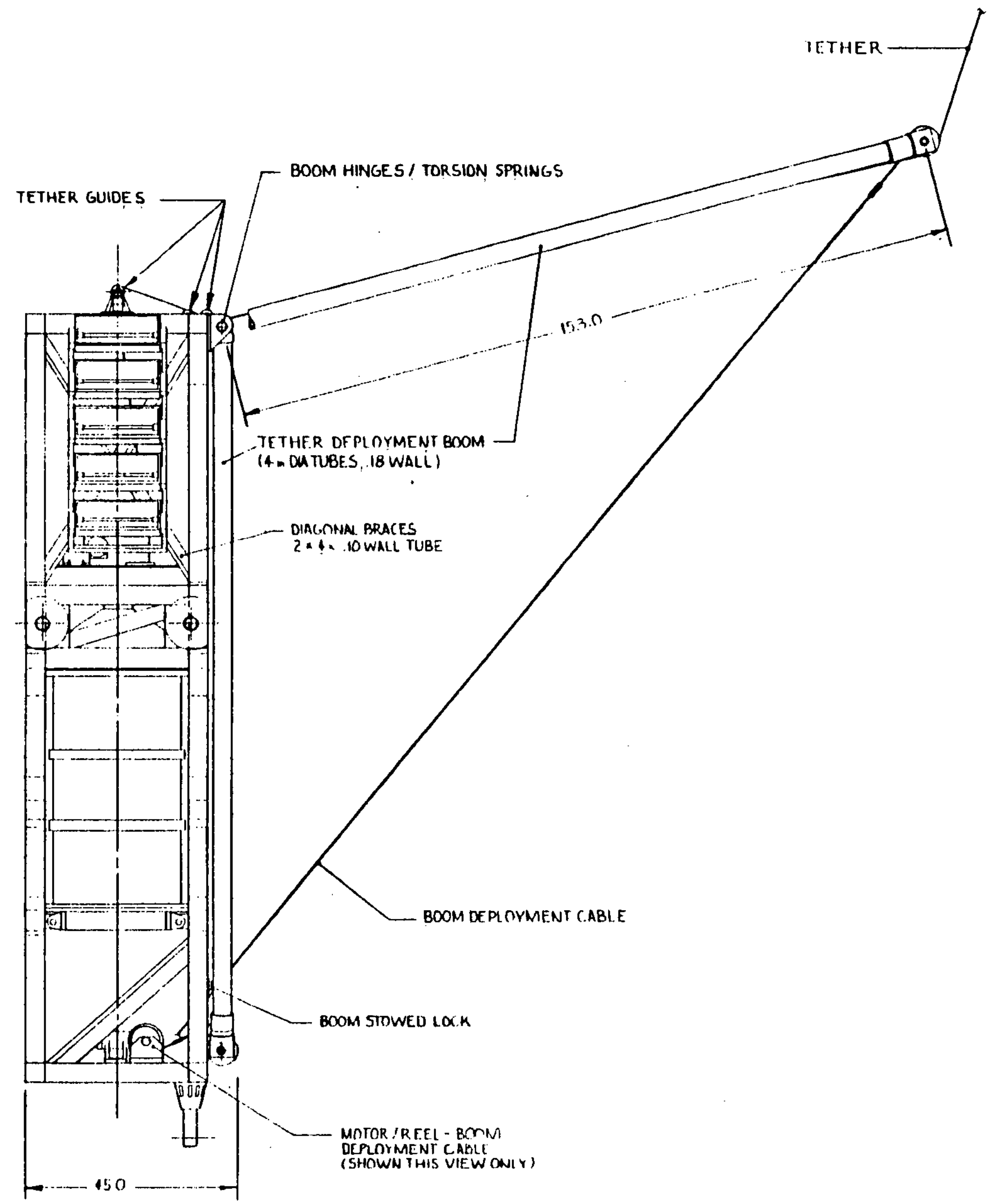
MIDTRM16

SHUTTLE TETHER DEPLOYMENT SYSTEM (STEDS)

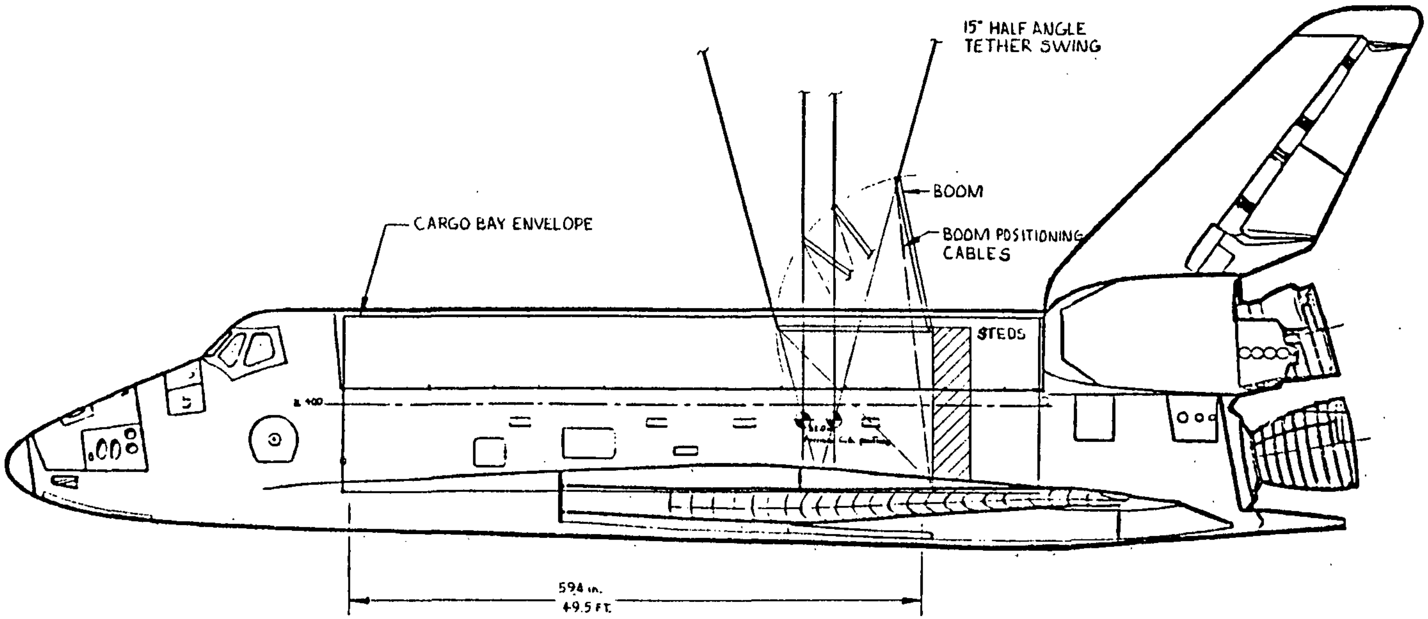


SHUTTLE TETHER DEPLOYMENT SYSTEM (STEDS)

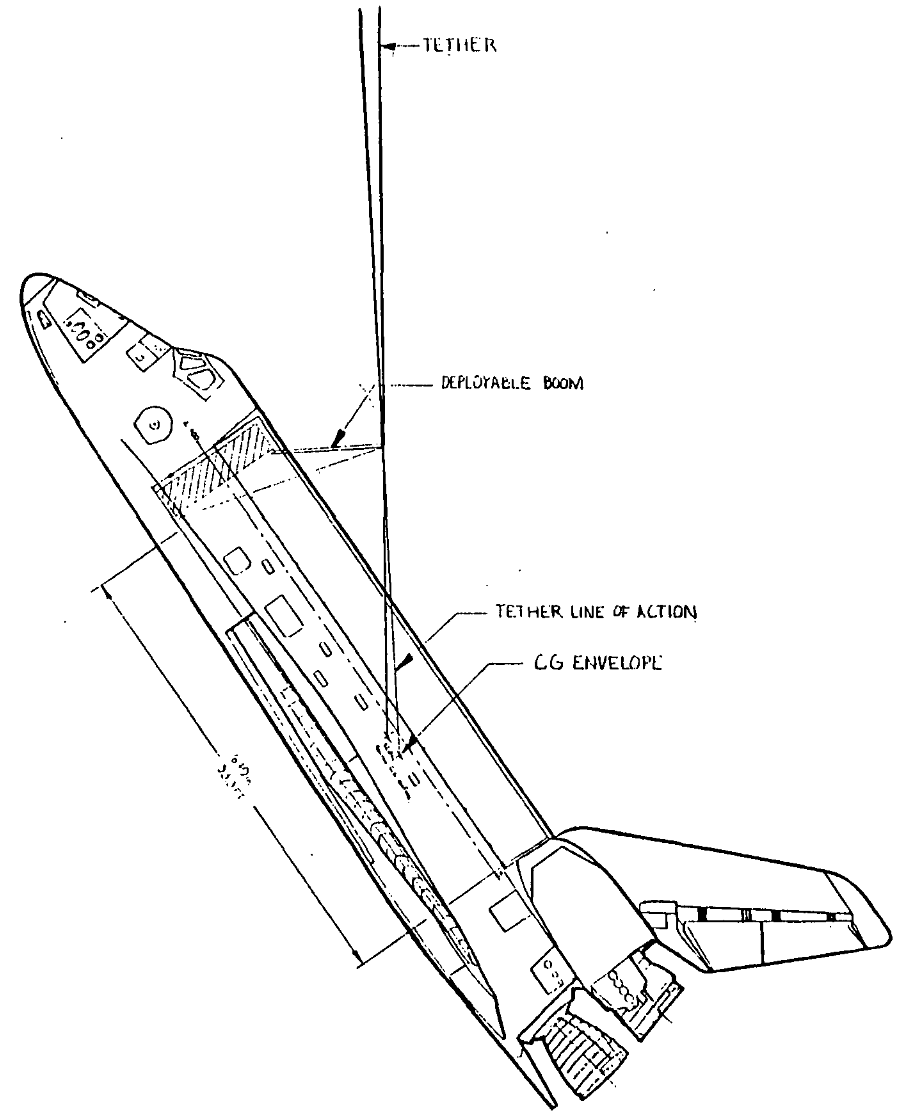
STEDS - SIDE VIEW



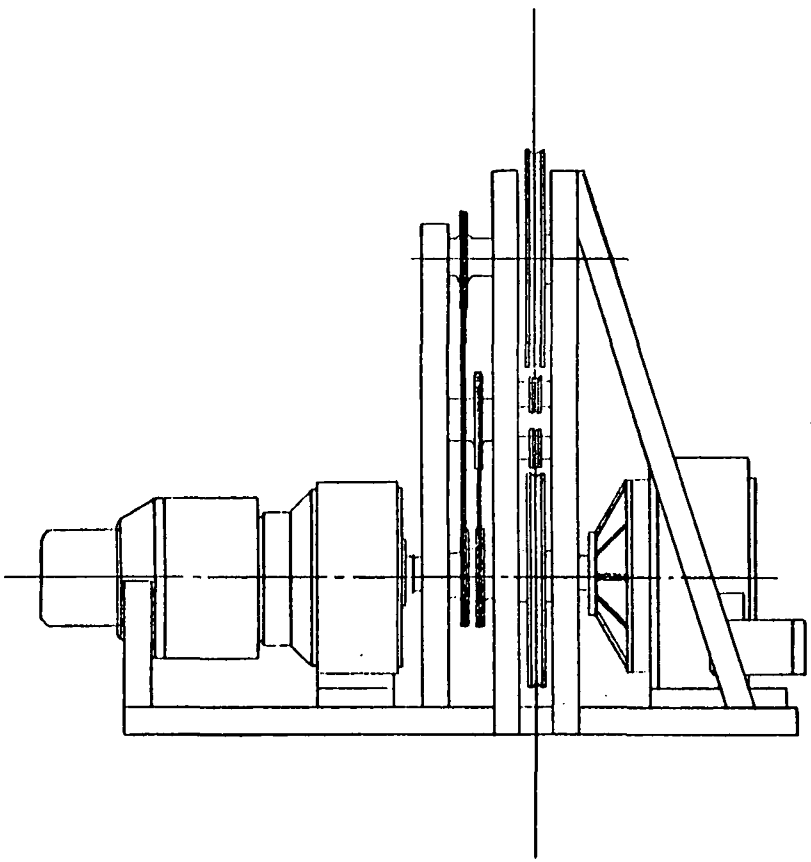
STEDS OPTIMALLY POSITIONED FOR TETHER FORCE ALIGNMENT THRU ORBITER CG

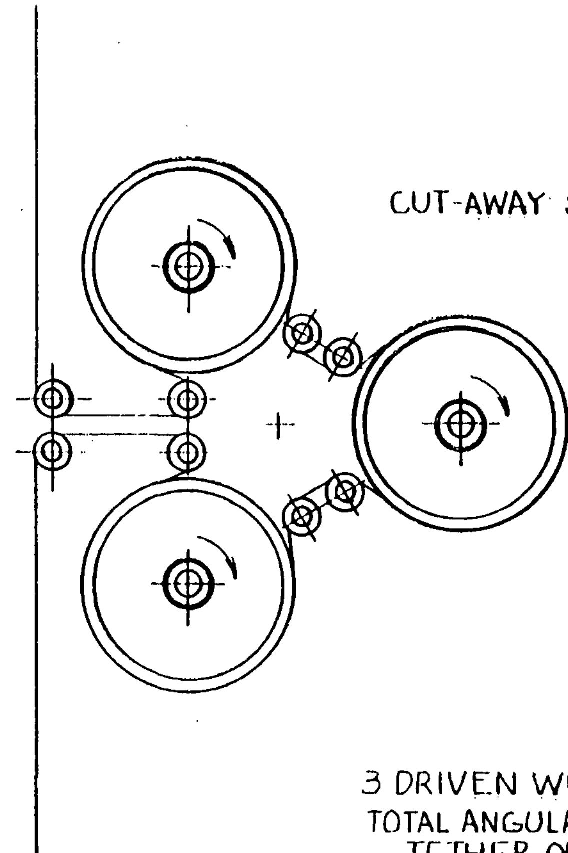


STEDS POSITIONED FOR MAXIMUM BAY LENGTH PAYLOAD CAPABILITY



STEDS TETHER DEPLOYMENT CONTROL CONCEPT





CUT-AWAY SIDE VIEW

$$\text{AMOUNT OF WRAP (RADIANS)} = \frac{\ln\left(\dfrac{\text{TENSION AFTER REEL}}{\text{TENSION BEFORE REEL}}\right)}{\text{FRICTION COEFFICIENT (TETHER, WHEEL)}}$$

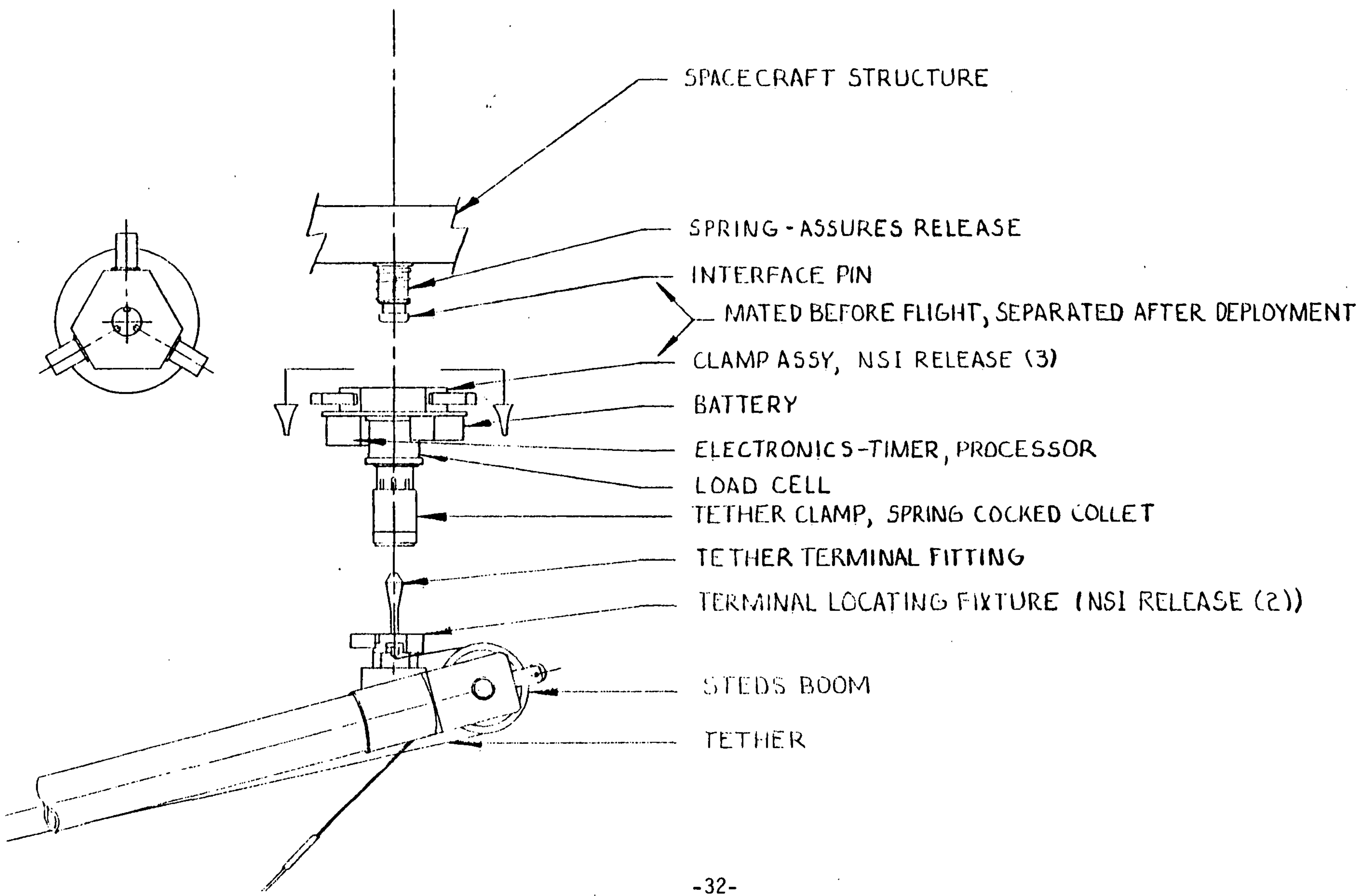
3 DRIVEN WHEELS

TOTAL ANGULAR WRAP –
TETHER ON WHEELS = 800°

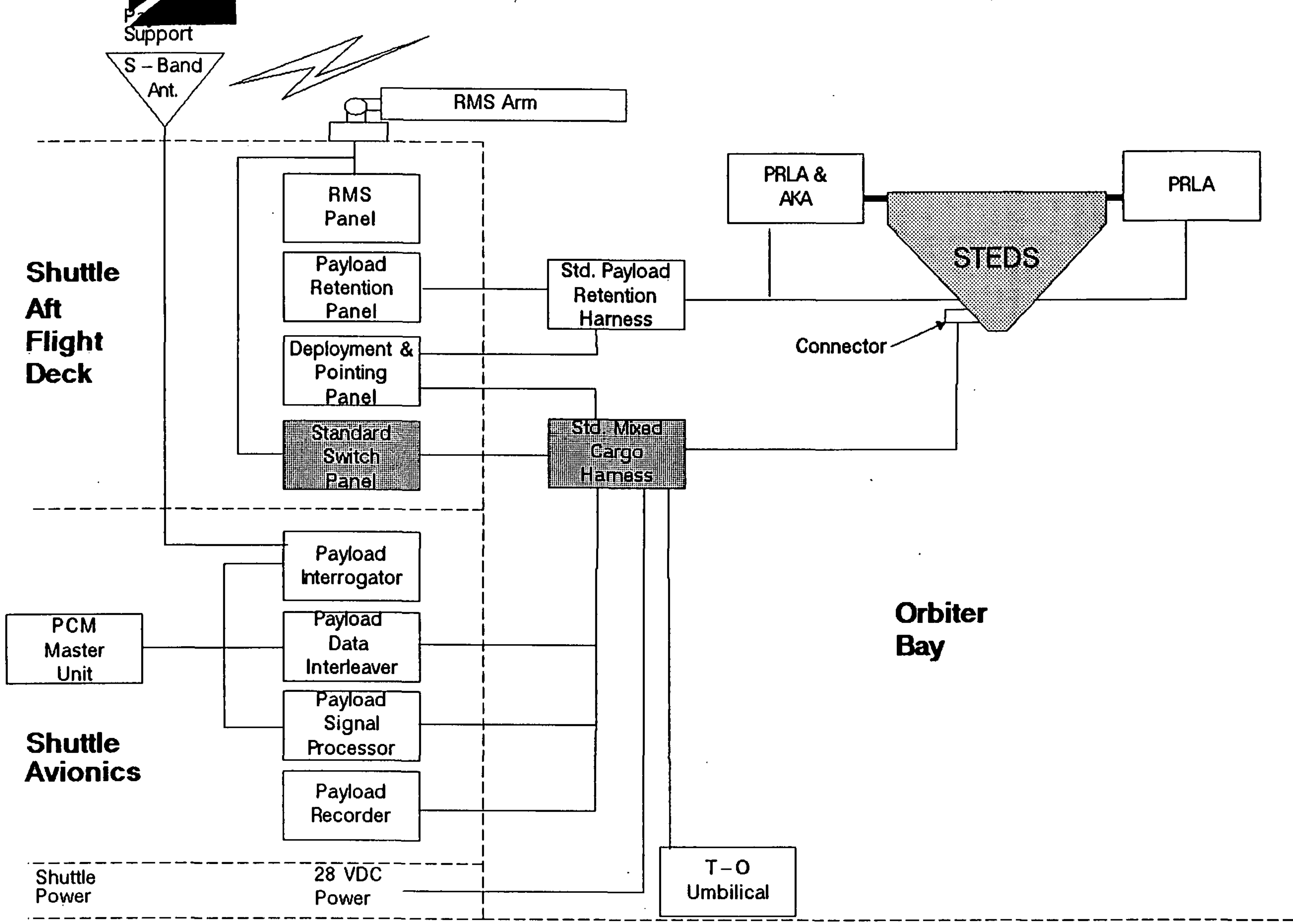
ASSUMPTIONS:

- TETHER-COATED WHEEL FRICTION $\mu = .5$
- TENSION IN = 1 LB.
- TENSION OUT = 755 LB. (MAX. EXPECTED x 1.2)

STEDS REMOTELY MATEABLE TETHER END EFFECTOR CONCEPT



STEDS/STS Electrical Interface



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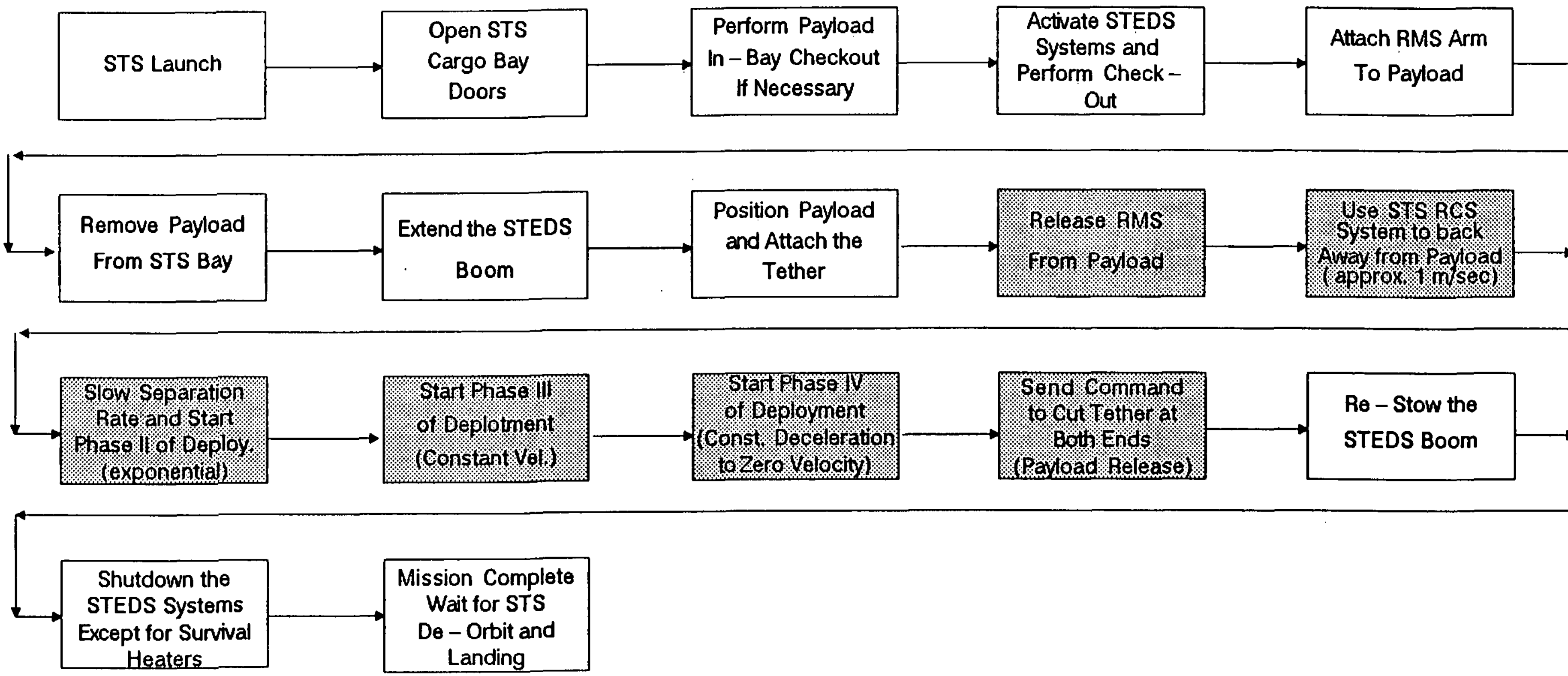
MIDTRM19

STEDS Operational Sequence



STEDS Performs Payload Deployment

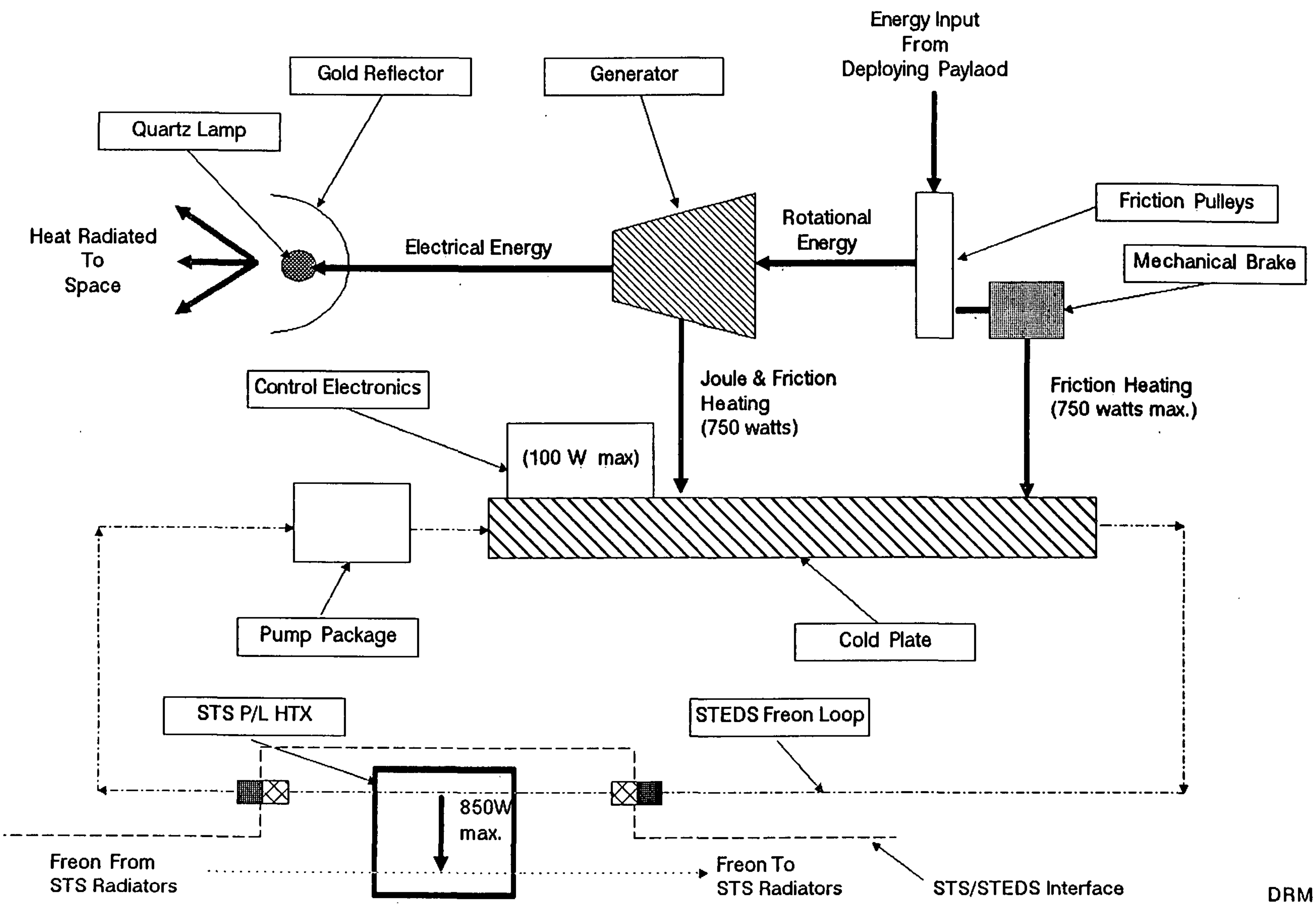
DRM MIDTRM10

STEDS Thermal Control Design

- STS Fluid Loop is Used to Cool the Generator and Electronics
- High Temperature Quartz Lamps Radiate Generator Power to Space
  + Same Type of Lamp Used for STS Bay Illumination
  + Ten 1600 Watt Quartz Lamps
  + Gold Plated Stainless Steel Reflectors Mounted Behind Each Lamp
- Exterior of Tether Container Covered With MLI
- Generator, Electronics and Brake Mounted on Fluid Cold Plate
  + Uses STS Freon Loop to Dump About 850 W
  + Up to 16 kW Radiated by Lamps

MIDTRM9

STEDS Thermal Control Concept



DRM MIDTRM11

STEDS Tension – Only Deployment Simulation Results

by

Dr. John Glaese
Control Dynamics Company

MIDTRM20

Cost Analysis

Approach & Preliminary Results

(Tim Patton)

MIDTRM28

Cost Analysis

– BASD'S LCC ANALYSIS APPROACH

– COSTING METHODOLOGY

– COST WBS FOR DEPLOYMENT CONCEPTS
  + MOMV
  + STEDS

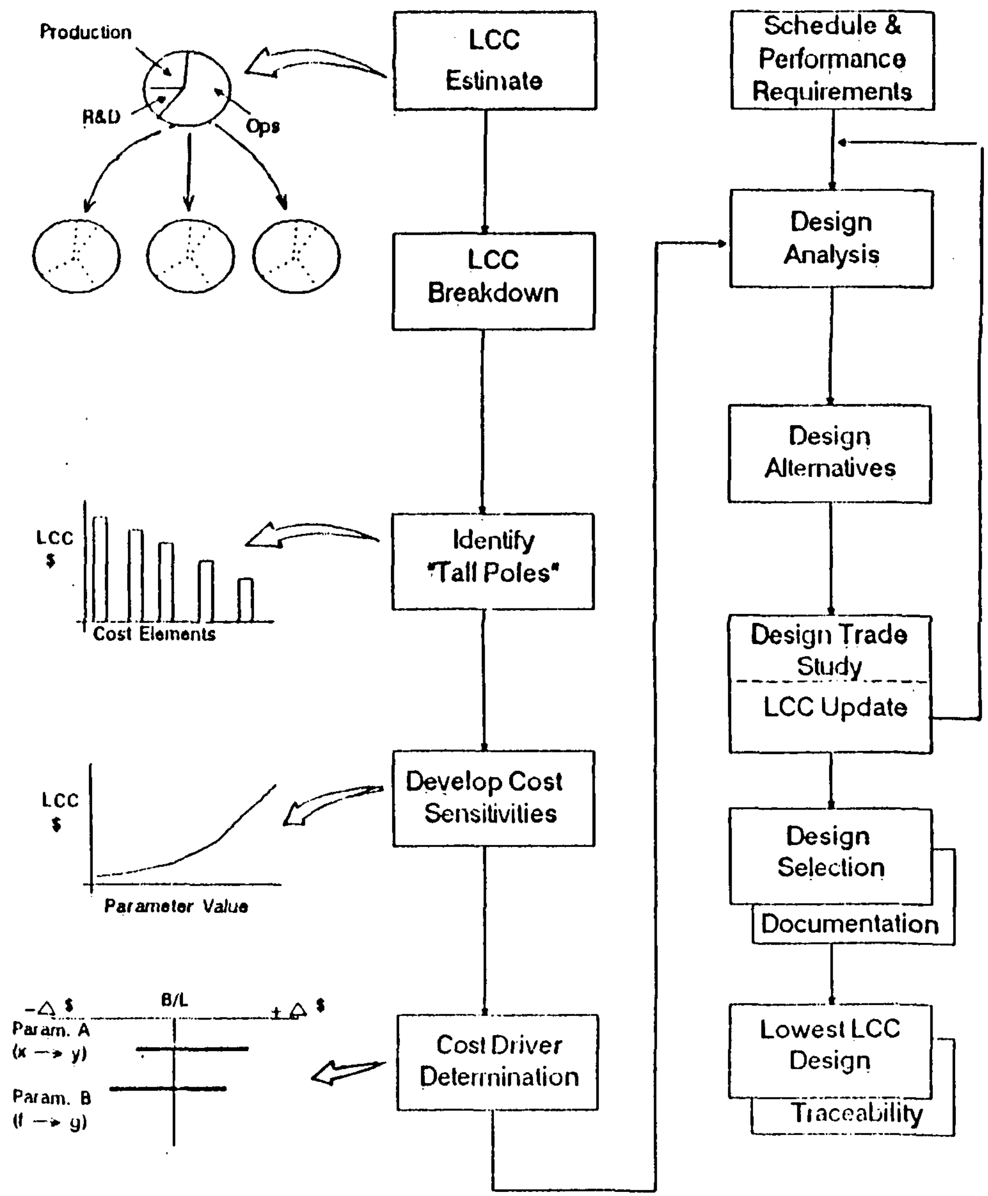
– RCA PRICE MODEL
  + PARAMETRIC ESTIMATING
  + SAMPLE PRICE INPUT SHEET
  + SAMPLE PRICE OUTPUT

– GROUNDRULES & ASSUMPTIONS

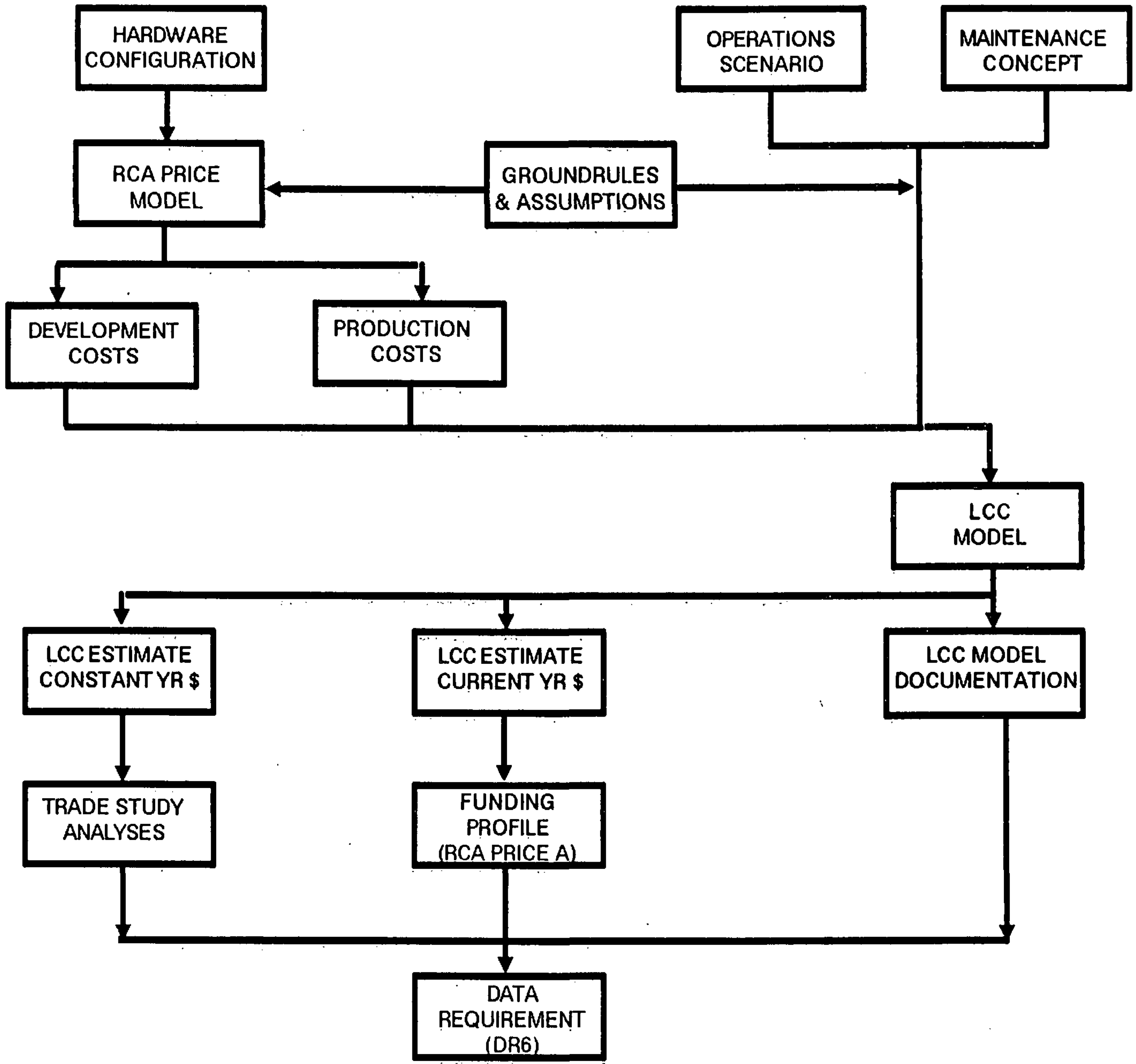
– LIFE CYCLE COST MODEL
  + MOMV (PRELIMINARY)
  + STEDS (PRELIMINARY)

ID DAN1

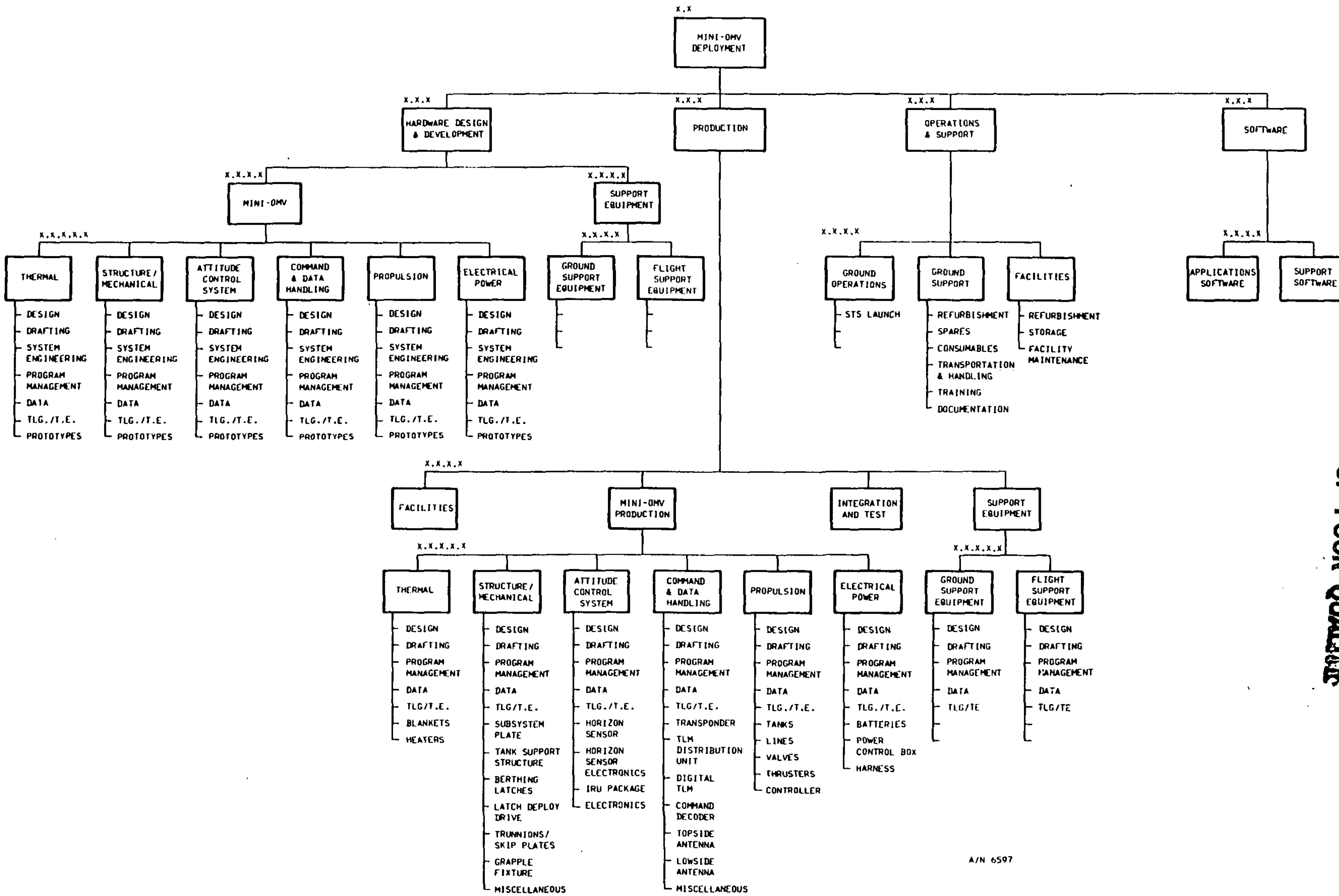
LCC Analysis Approach



BASD Costing Methodology



ID DAN2



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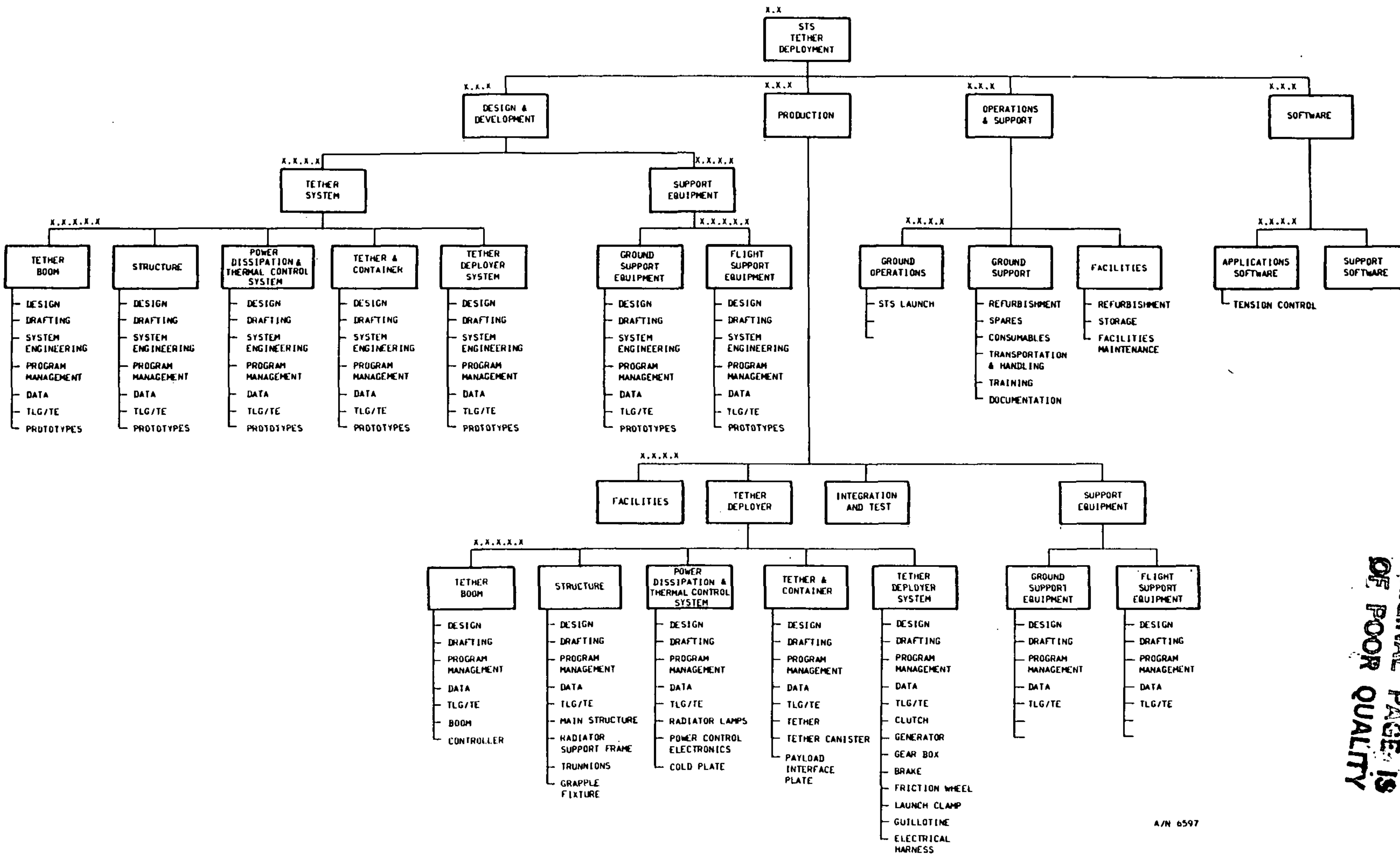
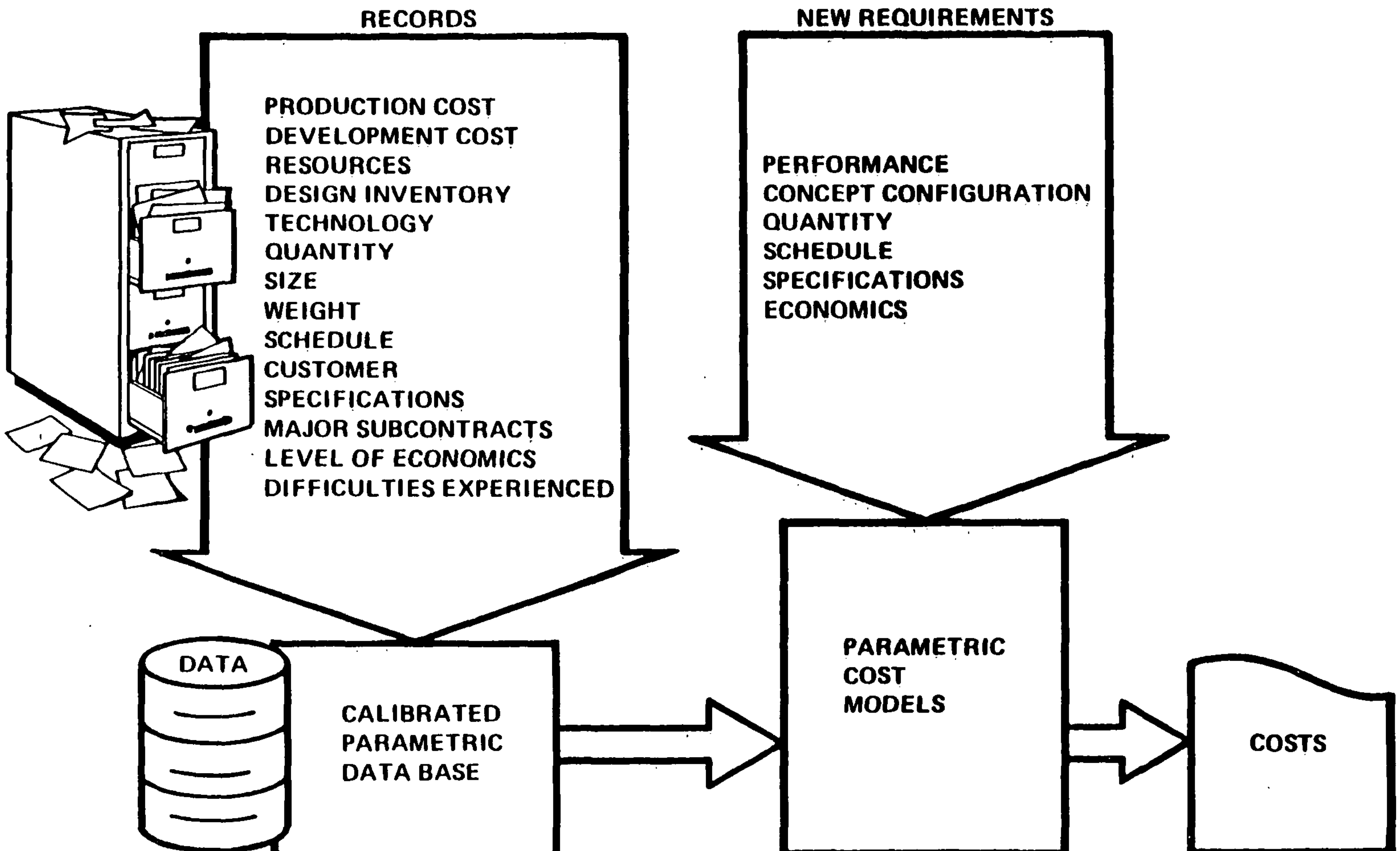

X.X
STS TETHER DEPLOYMENT
X.X.X
DESIGN & DEVELOPMENT
X.X.X
PRODUCTION
X.X.X
OPERATIONS & SUPPORT
X.X.X
SOFTWARE
X.X.X.X
TETHER SYSTEM
X.X.X.X
SUPPORT EQUIPMENT
X.X.X.X.X
TETHER BOOM
STRUCTURE
POWER DISSIPATION & THERMAL CONTROL SYSTEM
TETHER & CONTAINER
TETHER DEPLOYER SYSTEM
DESIGN
DRAFTING
SYSTEM ENGINEERING
PROGRAM MANAGEMENT
DATA
TLG/TE
PROTOTYPES
X.X.X.X.X
GROUND SUPPORT EQUIPMENT
FLIGHT SUPPORT EQUIPMENT
X.X.X.X
GROUND OPERATIONS
STS LAUNCH
GROUND SUPPORT
REFURBISHMENT
SPARES
CONSUMABLES
TRANSPORTATION & HANDLING
TRAINING
DOCUMENTATION
FACILITIES
REFURBISHMENT
STORAGE
FACILITIES MAINTENANCE
X.X.X.X
APPLICATIONS SOFTWARE
TENSION CONTROL
SUPPORT SOFTWARE
X.X.X.X
FACILITIES
TETHER DEPLOYER
INTEGRATION AND TEST
SUPPORT EQUIPMENT
X.X.X.X.X
TETHER BOOM
DESIGN
DRAFTING
PROGRAM MANAGEMENT
DATA
TLG/TE
BOOM
CONTROLLER
STRUCTURE
DESIGN
DRAFTING
PROGRAM MANAGEMENT
DATA
TLG/TE
MAIN STRUCTURE
RADIATOR SUPPORT FRAME
TRUNNIONS
GRAPPLE FIXTURE
POWER DISSIPATION & THERMAL CONTROL SYSTEM
DESIGN
DRAFTING
PROGRAM MANAGEMENT
DATA
TLG/TE
RADIATOR LAMPS
POWER CONTROL ELECTRONICS
COLD PLATE
TETHER & CONTAINER
DESIGN
DRAFTING
PROGRAM MANAGEMENT
DATA
TLG/TE
TETHER
TETHER CANISTER
PAYLOAD INTERFACE PLATE
TETHER DEPLOYER SYSTEM
DESIGN
DRAFTING
PROGRAM MANAGEMENT
DATA
TLG/TE
CLUTCH
GENERATOR
GEAR BOX
BRAKE
FRICTION WHEEL
LAUNCH CLAMP
GUILLOTINE
ELECTRICAL HARNESS
GROUND SUPPORT EQUIPMENT
DESIGN
DRAFTING
PROGRAM MANAGEMENT
DATA
TLG/TE
FLIGHT SUPPORT EQUIPMENT
DESIGN
DRAFTING
PROGRAM MANAGEMENT
DATA
TLG/TE
A/N 6597

RCA
PRICE
Systems

Parametric Cost Estimating Process



GC 1614

RCA
PRICE
Systems

Parametric Estimating Method

DISADVANTAGES

- BLACK MAGIC AURA
- NIH – CAN'T FIT
- LACKS DETAILS
  - MAN HOURS
  - WAGE RATES
  - OVERHEAD
- REQUIRES SPECIAL TRAINING

ADVANTAGES

- REQUIRES LITTLE INPUT DETAIL
- FAST/INEXPENSIVE
- TABLES FOR NORM PROVIDED
- CAN BE CALIBRATED
  - MANUFACTURE
  - VENDOR
- DISCIPLINED
  - NO OVERSIGHTS
  - NO DOUBLE ACCOUNTING
  - DISTORTION NORMALIZED
- PERPETUAL RETENTION OF EXPERIENCE

GC 1614

PRICE Input Data Worksheet

Basic Modes

File name: MOMV
Sheet ___ of ___

Title: MOMV Subsystem Plate

Date: 6-2-86

General A	Production Quantity QTY: 1	Prototypes PROTOS: 0	Weight (lbs) WT: 141	Volume (ft^3) VOL: 12.8	Mode, HW/SW Integration MODE . HSINT: 2	
General B	Quantity/Next Higher Assembly QTYNHA: 1	NHA Integration Factors Electronic INTEGE: 0	NHA Integration Factors Structural INTEGS: .5	Specification Level PLTFM: 2.0	Year of Economics YRECON:	Year of Technology YRTECH:
Mechanical/ Structural	Structure Weight WS: 141	Manufacturing Complexity MCPLXS: 6.2	New Structure NEWST: .7	Design Repeat DESRPS:	Mechanical Reliability MREL:	
Electronics	WE Per Ft^3 WECF / Volume Fraction USEVOL:	Manufacturing Complexity MCPLXE:	New Electronics NEWEL:	Design Repeat DESRPE:	Electronic Reliability EREL:	
Development	Development Start DSTART: 187	1st Prototype Complete DFPRO: C	Development Complete DLPRO: C	Engineering Complexity ECMPLX: 1.0	Tooling & Test Equip. DTLGTS:	Prototype Activity PROSUP:
Production	Production Start PSTART: 188	First Article Delivery PFAD: C	Production Complete PEND: C	PRICE-Improvement Factor PIF: .95	Tooling & Test Equip. PTLGTS:	Rate/Month Tooling RATOOL:
Actual Cost Data (Mode 7 only)	Average Unit AUCOST:	Production Total PTCOST:	Prototypes PRCOST:	Development Total DTCOST:		

Notes:
ESC = 100
PMULT = 1.185
NSHIFT = 2

ORIGINAL PAGE IS OF POOR QUALITY

1 ELECTRONIC ITEM
2 MECHANICAL ITEM
6 MODIFIED ITEM
7 ECIRP

GC 1613 1/85

RCA

- - - PRICE HARDWARE MODEL - - -
MECHANICAL ITEM

INPUT FILENAME: momv4	27-JUN-86 09:39	GLOBAL FILENAME:	
	(186056)	ESCALATION FILENAME:	

STRUCTURE-SUBSYSTEM PLATE

PRODUCTION QUANTITY	1	UNIT WEIGHT	141.00	MODE	2
PROTOTYPE QUANTITY	0.000	UNIT VOLUME	12.80	QUANTITY/NHA	1

UNIT PROD COST 118.83 MONTHLY PROD RATE 0.00

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	196.	7.	203.
DESIGN	547.	24.	571.
SYSTEMS	108.	-	108.
PROJECT MGMT	67.	15.	82.
DATA	33.	9.	42.
SUBTOTAL(ENG)	952.	55.	1007.
MANUFACTURING			
PRODUCTION	-	119.	119.
PROTOTYPE	0.	-	0.
TOOL-TEST EQ	10.	5.	15.
SUBTOTAL(MFG)	10.	123.	134.
TOTAL COST	962.	179.	1141.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	141.000	ENGINEERING COMPLEXITY	1.000
DENSITY	11.016*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	6.200	PROTO SCHEDULE FACTOR	0.250*
NEW DESIGN	0.700	PLATFORM	2.000
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1987*
ENGINEERING CHANGES	0.014*	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.500	MTBF(FIELD)	58946*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 87	(10)	OCT 87*	(0)	OCT 87*	(10)
PRODUCTION	JAN 88	(11)	NOV 88*	(0)	NOV 88*	(11)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
ECONOMIC BASE	187*		
ESCALATION	100.00	DEVELOPMENT TOOLING	1.00*
T-1 COST	59.37*	PRODUCTION TOOLING	1.00*
AMORTIZED UNIT COST	178.80*	RATE TOOLING	0
DEV COST MULTIPLIER	1.00*	PRICE IMPROVEMENT FACTOR	0.950
PROD COST MULTIPLIER	1.18	UNIT LEARNING CURVE	0.904*

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	863.	161.	1025.
CENTER	962.	179.	1141.
TO	1114.	200.	1315.

Groundrules and Assumptions

(GENERAL)

1) LIFE CYCLE COST ESTIMATE IS IN CURRENT DOLLARS
2) COST TRADE STUDY RESULTS ARE IN CONSTANT DOLLARS (1986)
3) THE LCC ESTIMATE IS FOR A QUANTITY OF 1 FLIGHT ARTICLE
4) 1 YEAR DEVELOPMENT PHASE
5) 1 YEAR PRODUCTION PHASE
6) 10 YEAR OPERATIONAL PHASE
7) NO REDUNDANT SUBSYSTEMS

ID DAN3

Groundrules and Assumptions

(DESIGN AND DEVELOPMENT)

1) THE DEVELOPMENT SCHEDULE IS 1/87 TO 12/87 FOR BOTH MINI – OMV AND SHUTTLE TETHER DEPLOYER SYSTEM

2) THERE IS NO PROTOTYPE HARDWARE IN THE DEVELOPMENT PHASE

3) DEVELOPMENT COSTS ARE ESTIMATED USING THE RCA PRICE MODEL

(PRODUCTION)

1) PRODUCTION QUANTITY IS 1

2) NO NEW PRODUCTION FACILITIES ARE REQUIRED

3) PRODUCTION COST IS ESTIMATED USING THE RCA PRICE MODEL

ID DAN3A

Groundrules and Assumptions

(OPERATIONS AND SUPPORT)

1) 10 YEAR PERIOD OF SUPPORT

2) REFURBISHMENT OF THE DEPLOYMENT SYSTEM WILL BE DONE ON – SITE

3) FACILITIES ARE AVAILABLE ON – SITE FOR REFURBISHMENT ACTIVITIES

4) THE TETHER IS EXPENDABLE AFTER EACH MISSION

5) OPERATIONS WILL INCLUDE 25 MISSIONS OVER 10 YEARS

6) TETHER CANISTER WILL BE SENT TO TETHER VENDOR FOR TETHER REPLACEMENT AFTER EACH MISSION

7) MAINTENANCE TRAINING AND DOCUMENTATION FOR THE MOMV AND STEDS ARE ADDITIONAL COSTS AND ARE ACCOUNTED FOR IN THE LCC ESTIMATE

ID DAN4/

Mini-OMV

	Thermal	Structure	ACS	C&DH	Propulsion	Electrical	Subtotal
Design	$486,000	$2,245,000	$0	$273,000	$71,000	$120,000	$3,195,000
Drafting	$172,000	$823,000	$0	$87,000	$28,000	$48,000	$1,158,000
Systems Engineering	$59,000	$423,000	$0	$47,000	$5,000	$23,000	$557,000
Program Management	$57,000	$300,000	$0	$30,000	$10,000	$21,000	$418,000
Data	$27,000	$148,000	$0	$15,000	$5,000	$10,000	$205,000
Tooling & Equipment	$11,000	$52,000	$0	$8,000	$5,000	$19,000	$95,000
Prototypes	$0	$0	$0	$0	$0	$0	$0
Subtotal	$812,000	$3,991,000	$0	$460,000	$124,000	$241,000	$5,628,000

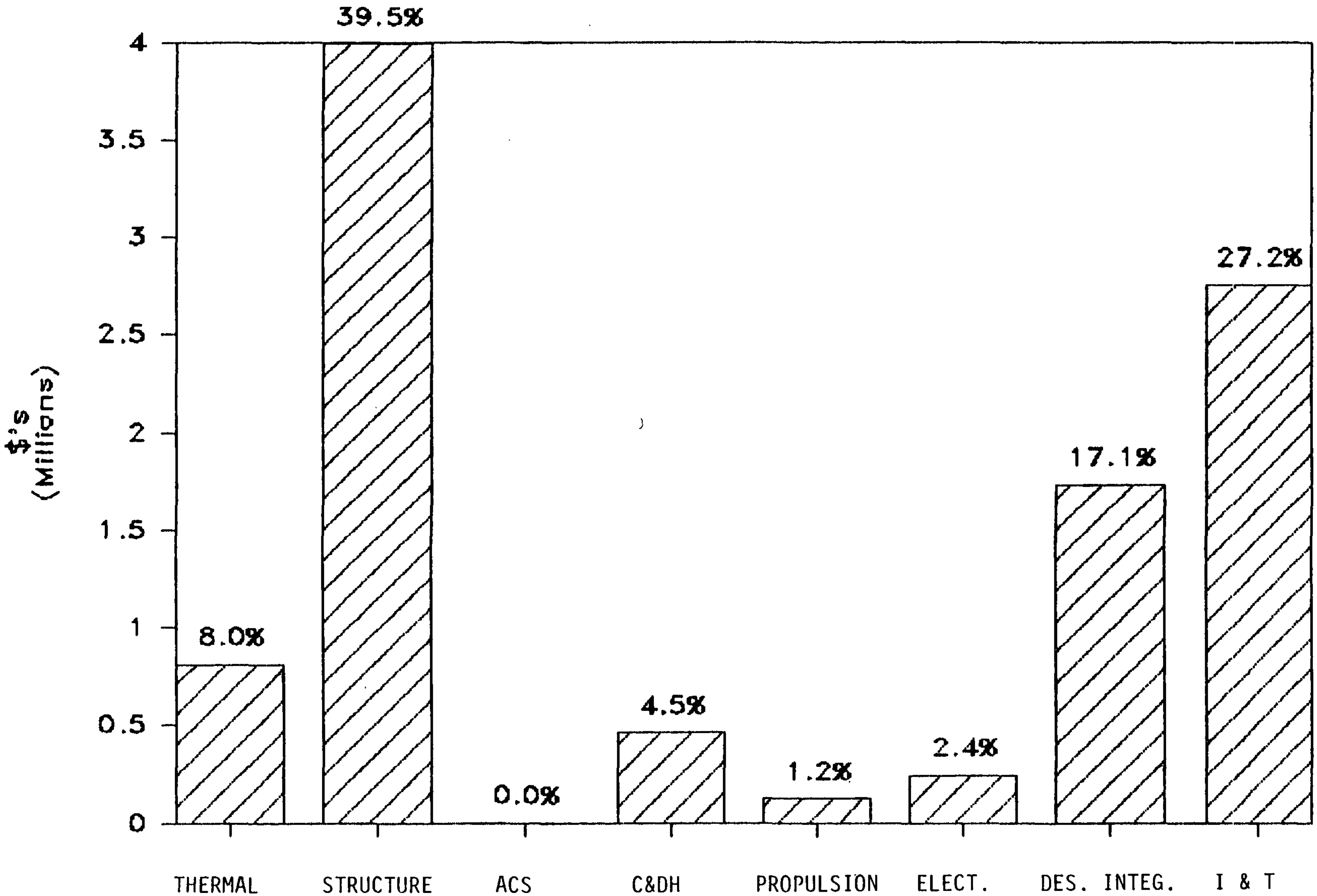
Support Equipment

	GSE	FSE	Subtotal
Design	$0	$0	$0
Drafting	$0	$0	$0
Systems Engineering	$0	$0	$0
Program Management	$0	$0	$0
Data	$0	$0	$0
Tooling & Equipment	$0	$0	$0
Prototypes	$0	$0	$0
Subtotal	$0	$0	$0

Design & Development Summary

	Total
Design	$3,195,000
Drafting	$1,158,000
Systems Engineering	$557,000
Program Management	$418,000
Data	$205,000
Tooling & Equipment	$95,000
Prototypes	$0
Design Integration	1,731,000
Integration & Test	2,755,000
Total	$10,114,000

MOMV DESIGN & DEVELOPMENT COST



Mini-OMV

	Thermal	Structure	ACS	C&DH	Propul.	Elect.	Subtotal
Design	$114,000	$141,000	$0	$20,000	$245,000	$357,000	$877,000
Drafting	$28,000	$42,000	$0	$6,000	$62,000	$115,000	$253,000
Program Management	$49,000	$94,000	$0	$8,000	$57,000	$96,000	$304,000
Data	$28,000	$55,000	$0	$5,000	$31,000	$53,000	$172,000
Tooling & Equipment	$16,000	$38,000	$0	$2,000	$13,000	$18,000	$87,000
Hardware	$363,000	$1,059,000	$1,685,000	$3,159,000	$2,206,000	$1,256,000	$9,728,000
Sub Total	$598,000	$1,429,000	$1,685,000	$3,200,000	$2,614,000	$1,895,000	$11,421,000
I&T							$1,485,000
Facilities							0
Subtotal							$12,906,000

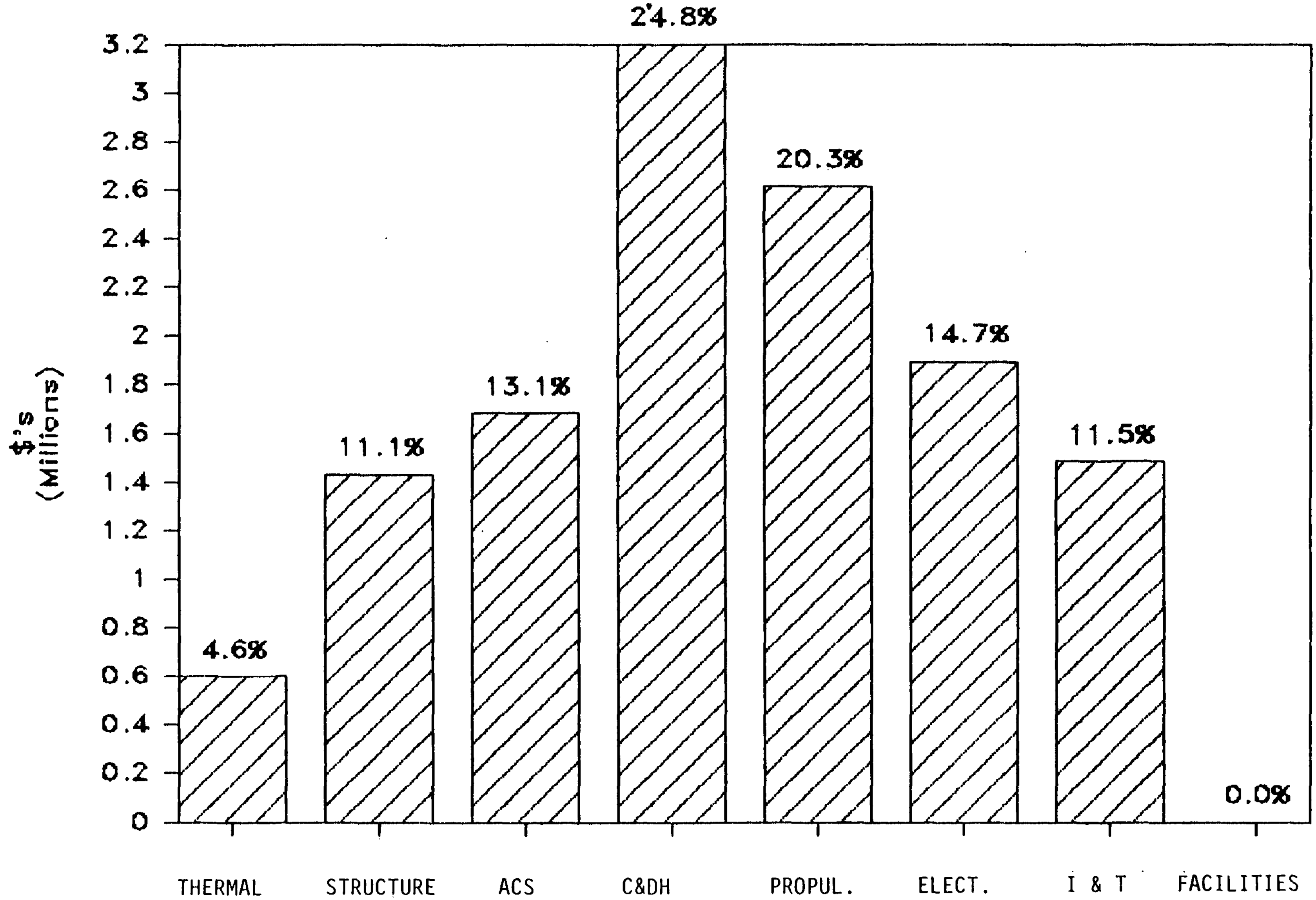
Support Equipment

	GSE	FSE	Subtotal
Design	$0	$0	$0
Drafting	$0	$0	$0
Program Management	$0	$0	$0
Data	$0	$0	$0
Tooling & Equipment	$0	$0	$0
Hardware	$0	$0	$0
Sub Total	$0	$0	$0

Production Summary

	Total
Design	$877,000
Drafting	$253,000
Program Management	$304,000
Data	$172,000
Tooling & Equipment	$87,000
Hardware	$9,728,000
I&T	$1,485,000
Facilities	0
Total	$12,906,000

MOMV HARDWARE PRODUCTION COST



Hardware Design & Development Cost

STEDS

	Thermal	Structure	Teth Cont	Teth Deploy	Boom	Subtotal
Design	$404,000	$1,463,000	$170,000	$145,000	$108,000	$2,290,000
Drafting	$161,000	$523,000	$69,000	$61,000	$49,000	$863,000
Systems Engineering	$29,000	$288,000	$23,000	$18,000	$9,000	$367,000
Program Management	$66,000	$180,000	$28,000	$27,000	$25,000	$326,000
Data	$29,000	$89,000	$13,000	$14,000	$12,000	$157,000
Tooling & Equipment	$9,000	$46,000	$14,000	$8,000	$6,000	$83,000
Prototypes	$0	$0	$0	$0	$0	$0
Subtotal	$698,000	$2,589,000	$317,000	$273,000	$209,000	$4,086,000

Support Equipment

	GSE	FSE	Subtotal
Design	$0	$0	$0
Drafting	$0	$0	$0
Systems Engineering	$0	$0	$0
Program Management	$0	$0	$0
Data	$0	$0	$0
Tooling & Equipment	$0	$0	$0
Prototypes	$0	$0	$0
Subtotal	$0	$0	$0

Design & Development Summary

	Total
Design	$2,290,000
Drafting	$863,000
Systems Engineering	$367,000
Program Management	$326,000
Data	$157,000
Tooling & Equipment	$83,000
Prototypes	$0
Design Integration	$778,000
Integration & Test	$848,000
Total	$5,712,000

STEDS

	Thermal	Structure	Teth Cont	Teth Deploy	Boom	Subtotal
Design	$288,000	$142,000	$58,000	$10,000	$27,000	$525,000
Drafting	$85,000	$42,000	$18,000	$2,000	$8,000	$155,000
Program Management	$75,000	$93,000	$36,000	$9,000	$17,000	$230,000
Data	$42,000	$54,000	$21,000	$5,000	$10,000	$132,000
Tooling & Equipment	$21,000	$38,000	$11,000	$2,000	$6,000	$78,000
Hardware	$378,000	$735,000	$485,000	$395,000	$134,000	$2,127,000
Sub Total	$889,000	$1,104,000	$629,000	$423,000	$202,000	$3,247,000
I&T						$234,000
Facilities						$0
Subtotal						$3,481,000

Support Equipment

	GSE	FSE	Subtotal
Design	$0	$0	$0
Drafting	$0	$0	$0
Program Management	$0	$0	$0
Data	$0	$0	$0
Tooling & Equipment	$0	$0	$0
Hardware	$0	$0	$0
Sub Total	$0	$0	$0

Production Summary

	Total
Design	$525,000
Drafting	$155,000
Program Management	$230,000
Data	$132,000
Tooling & Equipment	$78,000
Hardware	$2,127,000
I&T	$234,000
Facilities	$0
Total	$3,481,000

MOMV/STEDS Cost Comparison

	MOMV	STEDS
Hardware Design & Development	$10,114,000	$5,712,000
Hardware Production	$12,906,000	$3,481,000
Total Design & Production	$23,020,000	$9,193,000

MIDTRM29

Launch Cost Comparison

MOMV (48" length) $48" + 6" = 54"$

$$\frac{54"}{(720")(.75)} \times (\$111.0M) = \$11.1M/\text{launch}$$

x 25 launches

$\boxed{\$277.5M}$

STEDS(45" length) $45" + 6" = 51"$

$$\frac{51"}{(720")(.75)} \times (\$111.0M) = \$10.5M/\text{launch}$$

x 25 launches

$\boxed{\$262.5M}$

MIDTRM30

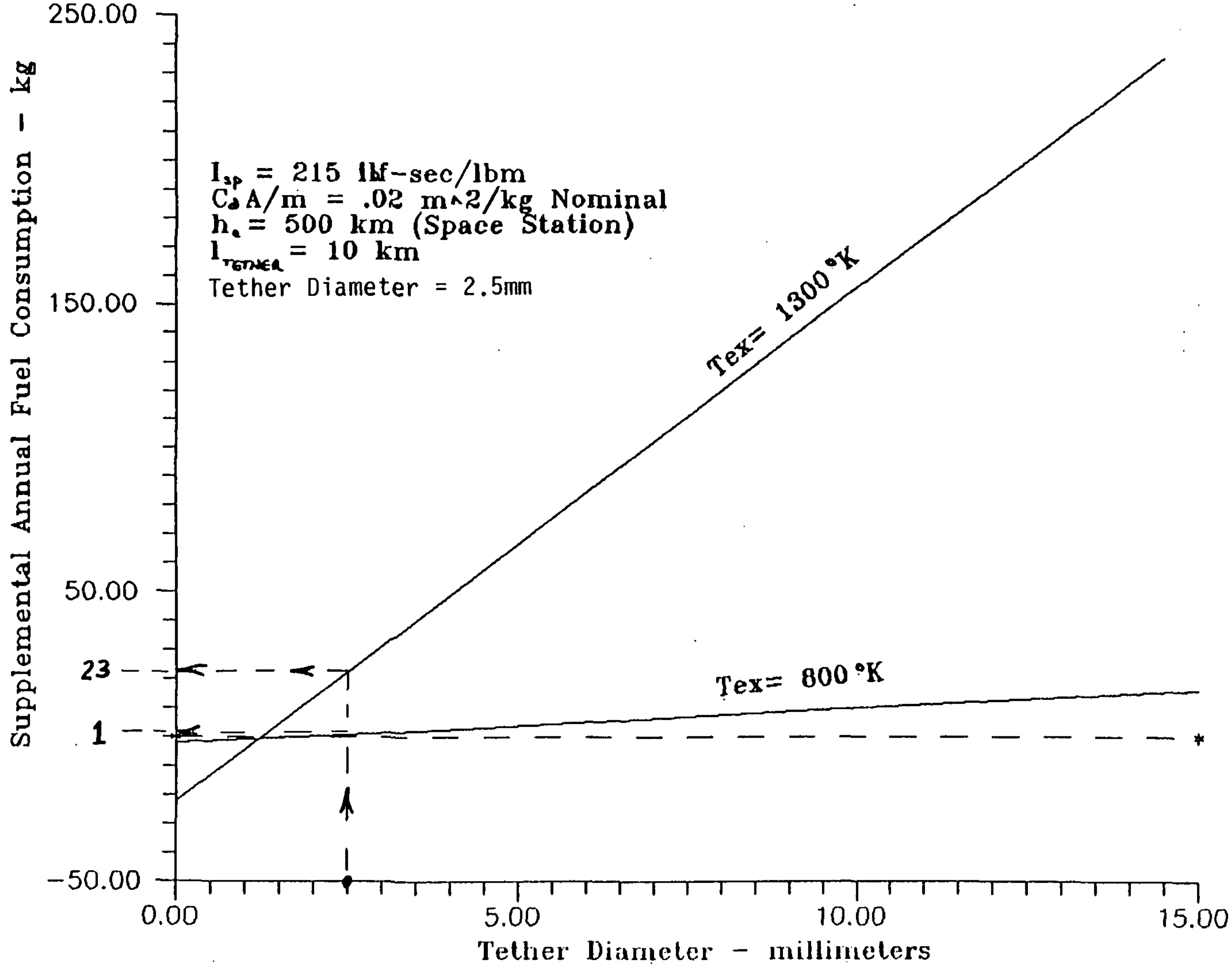
Tethered Platform Study

Analysis of Fuel Savings

Cal Rybak

MIDTRM21

Additional Fuel to Offset Tether Drag Less Savings Due to 10 km Higher Platform Altitude



Error Sources Contributing to Fuel Usage

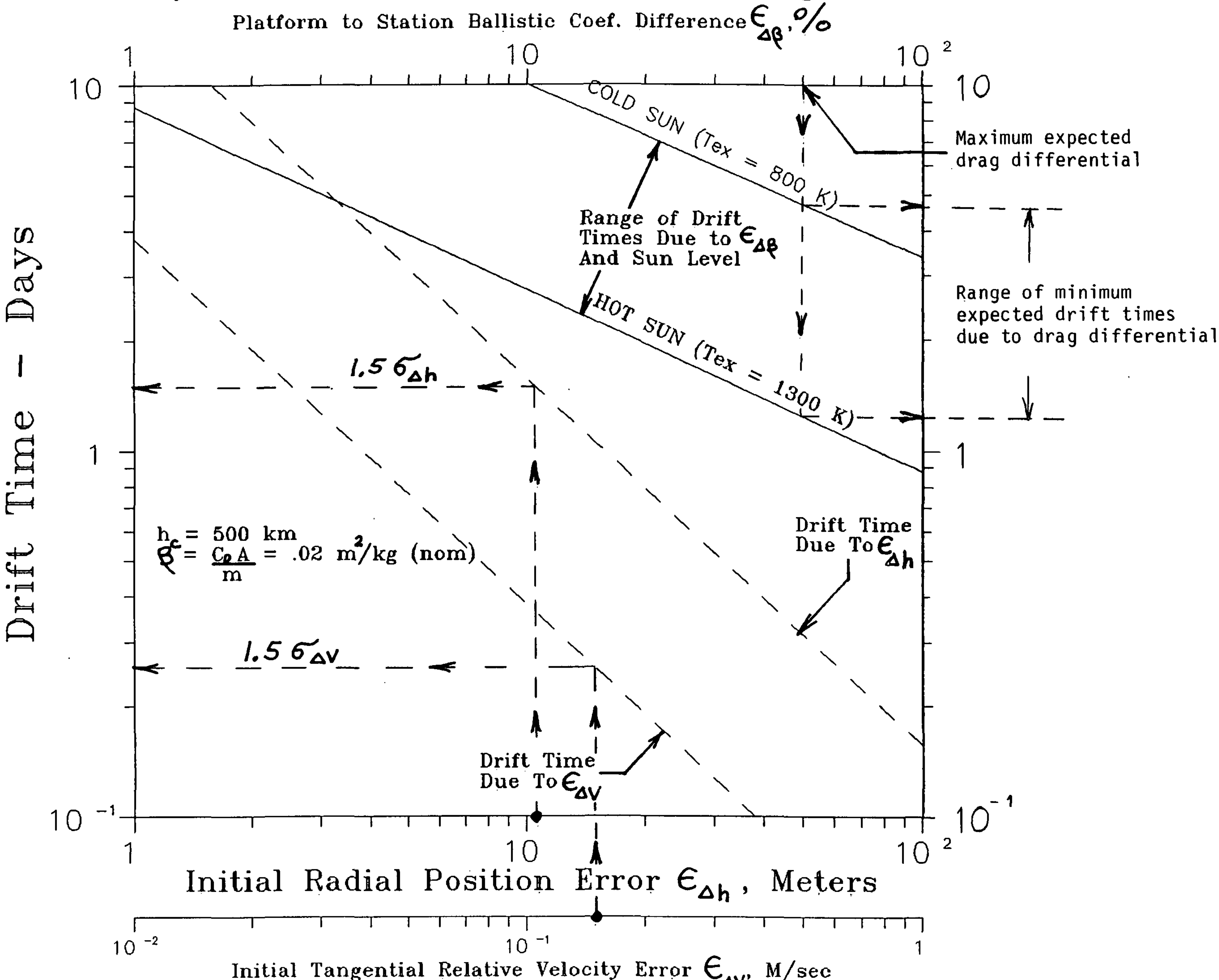
Ballistic Coef Differential (3σ)	GPS Radial Position Error (3σ,m)	GPS Tangential Velocity Error (3σ,m/sec)
50 %	21 [1]	0.3 [2]

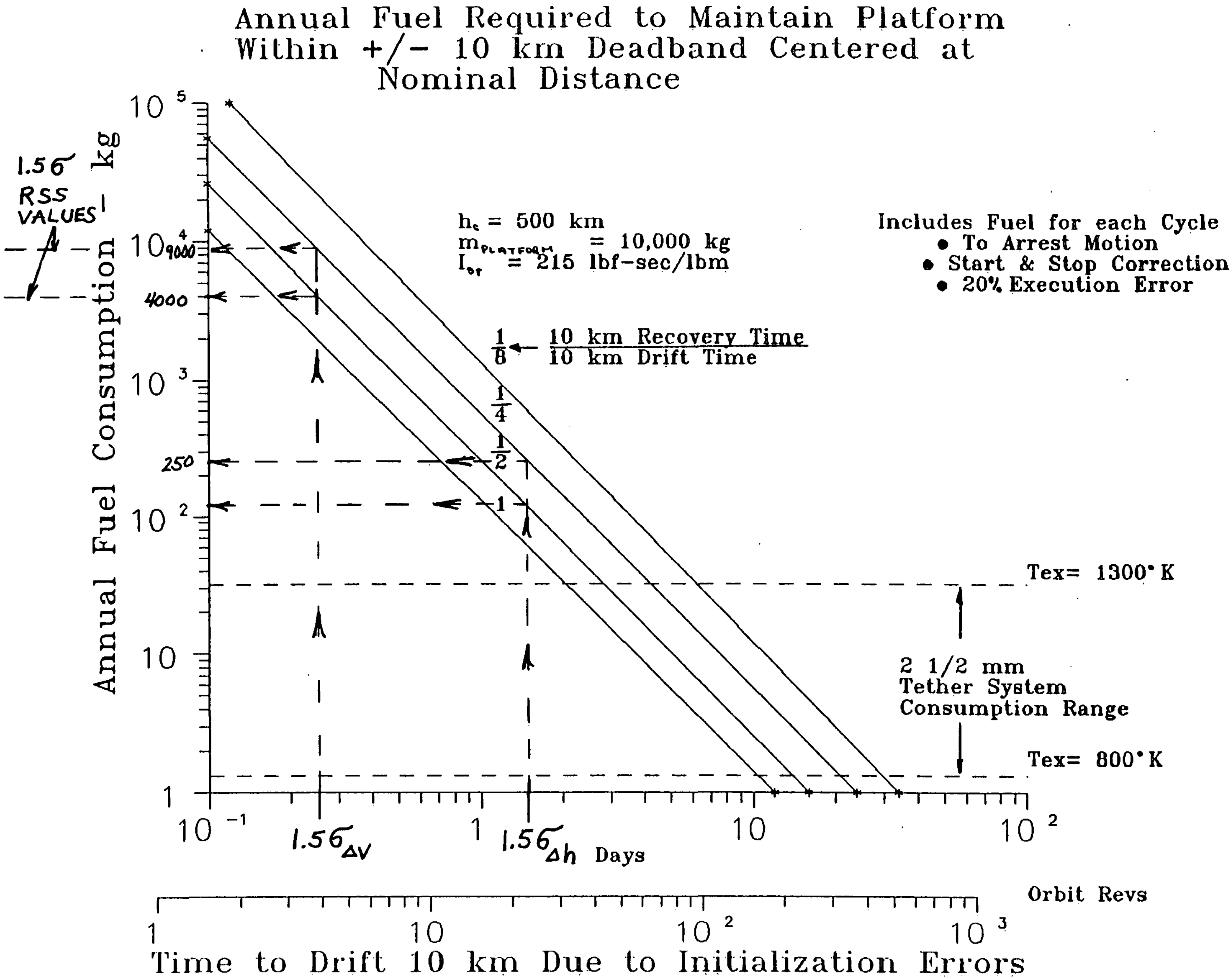
(1) Rss of 15m, 3σ Each for Individual Space Station and Platform Determinations

(2) Rss of 0.2 m/sec, 3σ Each for Individual Space Station and Platform Determinations

MIDTRM31

Days to Drift 10 km From Nominal Separation Distance





Annual Fuel Required to Maintain Platform Within +/- 10 km Deadband Centered at Nominal Distance
Annual Fuel Consumption kg
1.5σ RSS VALUES
9000
4000
250
h_c = 500 km
$m_{PLATFORM}$ = 10,000 kg
I_{sp} = 215 lbf-sec/lbm
Includes Fuel for each Cycle
• To Arrest Motion
• Start & Stop Correction
• 20% Execution Error
1/8 ← 10 km Recovery Time / 10 km Drift Time
1/4
1/2
1
Tex= 1300° K
2 1/2 mm Tether System Consumption Range
Tex= 800° K
$1.5\sigma_{\Delta V}$
$1.5\sigma_{\Delta h}$
Days
Orbit Revs
Time to Drift 10 km Due to Initialization Errors

Propellant Cost Savings Due To Tethering Platform

Min. Propellant Cost Savings – $\frac{2000 \times 2.2}{(65000)(.75)} \times \$111M = \$10M/yr$

Nom. Propellant Cost Savings – $\frac{4000 \times 2.2}{(65000)(.75)} \times \$111M = \$20M/yr$

Max. Propellant Cost Savings – $\frac{9000 \times 2.2}{(65000)(.75)} \times \$111M = \$45M/yr$

MIDTRM33

Results From Tethered Platform Studies

– Primary Cost Benefit of Tethered Platform is in Station Keeping Fuel Savings Which Can Range Between $100M and $450M Over The Initial 10 Years of Operation

– Other Areas of Potential Cost Savings (i.e. Power Tether, Comm.) are Small Compared to the Fuel Cost Savings

– Future Studies Should Evaluate the Cost Impact of Beefing up the Space Station Structure to Withstand the Tether Tension Loads

MIDTRM32

Tasks To Be Completed

- STEDS/MOMV Cost Analysis
- Tether Crawler Design and Costing
- LCC Cost Models & Documentation
- Final Report